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Removal of Hazardous Material Spills from Bottoms of Flowing Waterbodies

Rexnord, Inc.
Milwaukee, WI

Prepared for

Municipal Environmental Research Lab.
Cincinnati, OH

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FOREWORD

The U.S. Environmental Protection Agency was created because of increasing public and government concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water, and spoiled land are tragic testimonies to the deterioration of our natural environment. The complexity of that environment and the interplay of its components require a concentrated and integrated attack on the problem.

Research and development is that necessary first step in problem solution; it involves defining the problem, measuring its impact, and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems to prevent, treat, and manage wastewater and solid and hazardous waste pollutant discharges from municipal and community sources, to preserve and treat public drinking water supplies, and to minimize the adverse economic, social, health, and aesthetic effects of pollution. This publication is one of the products of that research and provides a most vital communications link between the researcher and the user community.

This report documents the laboratory studies and field demonstrations conducted to determine the feasibility of removing spilled insoluble hazardous materials from the bottoms of flowing watercourses. As such, it serves as a reference to state, local, and Federal agencies, the chemical and transportation industries, and others interested in the control of hazardous material spills. This project is a part of a continuing program of the Oil and Hazardous Materials Spills Branch, MERL-Ci, to assess and mitigate the environmental impact of pollution from hazardous materials spills.

Francis T. Mayo
Director
Municipal Environmental Research
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This report documents the results of a study to determine the feasibility of removing spilled insoluble hazardous materials from the bottom of flowing watercourses. Descriptions are given of two full-scale systems developed to suck up spilled materials and contaminated bottom mud, remove excess water from the pumped slurry, and decontaminate the water removed so that it can be returned to the stream. The two systems that were developed by Rex Chainbelt and Industrial Bio-Test, respectively, were demonstrated at the Little Menomonee River in Milwaukee, Wisconsin, the bottom of which was laden with spilled creosote. These demonstrations indicate that spilled hazardous materials can be removed from the bottoms of small watercourses by suction dredging.

This work was submitted in fulfillment of contract numbers 68-03-0181 and 68-03-0182 by Rex Chainbelt Corporation and by Industrial Bio-Test, respectively, under the sponsorship of the U.S. Environmental Protection Agency. This report covers the period July 1972 to December 1974 and the work was completed as of January 1977.

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CONVERSION FACTORS

To convert from	To	Multiply by
foot (ft)	meter (m)	3.048×10^{-1}
foot^2 (ft^2)	meter^2 (m^2)	9.2903×10^{-2}
degree Fahrenheit (°F)	degree Celsius (°C)	$T_C = (T_F - 32)/1.8$
gallon (gal)	liter (L)	3.7854
	meter^3 (m^3)	3.7854×10^{-3}
inch (in)	centimeter (cm)	2.5400
	meter (m)	2.5400×10^{-2}
inch^2 (in^2)	meter^2 (m^2)	6.4516×10^{-4}
mile (mi)	kilometer (km)	1.6093
	meter (m)	1609.3
pounds/inch^2 (psi)	Pascals (p)	6894.7
pounds (lb)	kilograms (kg)	0.454
yard^3 (yd^3)	meter^3(m^3)	0.7645

SECTION 1

INTRODUCTION

PURPOSE OF PROJECT

In the past several years increasing concern has been focused on pollution caused by spills of hazardous materials. This concern has been evidenced by Section 311 of the Water Pollution Control Act Amendments of 1972 (PL 92-500) which, among other things, charge the U.S. Environmental Protection Agency (EPA) with the responsibility for identification, control, and removal methods for spills of designated hazardous materials. No designation list of hazardous substances has yet been promulgated as of this writing, but when it is, three broad categories of hazardous wastes will be defined, depending on physical behavior in water: floating, dissolving, and sinking. These classifications are the most useful in designing systems to control and remove spills.

EPA and several others have studied environmentally safe methods for removing oil spills from water for several years. With minor modifications, these methods are expected to have wide applicability in the removal of floating spilled hazardous materials. Removal methods for spilled materials that dissolve or sink, however, have been neglected until relatively recently.

This study seeks environmentally safe methods for solving the threefold problem of: (1) removing spilled hazardous chemicals from the bottom of small flowing watercourses, (2) separating the bottom mud and chemical from the associated water, so that the amount of material to be disposed is not overwhelming, and (3) treating the associated water so that it can be returned to the stream without endangering downstream ecology or water uses.

To accomplish this end, several key steps were taken: (1) a suitable set of system design goals was developed, (2) a suitable test site was selected and approvals for its use were secured, (3) contracts for performance of the work were procured, and (4) the work detailed in this report was performed.

SYSTEM DESIGN GOALS

The optimum system for removing spilled hazardous materials from the bottoms of small watercourses must have several general characteristics: It must be small enough to maneuver and operate in remote streams or lakes where the banks are covered with vegetation and/or rocks or rock outcropping. It must be capable of removing the spilled material with a minimum of damage to the natural stream bed and stream banks. Removal operations must result in minimum resuspension of spilled contaminant and natural inert solids into the water column. Separation of contaminant and bottom solids (sludge) from associated stream water must result in a logistically manageable volume of sludge in a form suitable for ultimate disposal and in processed water that is acceptable for discharge back to the stream. The manner in which the processed water is returned to the stream should not erode the stream bed or banks or resuspend inert solids. And the sludge produced must be disposed of in an approved manner.

The first characteristic, compact size and mobility, is considered vital, since the removal equipment may have to be deliverable within a short period of time to stream locations that may not be accessible to the large barges (suction dredges) or heavy earth-moving equipment (draglines) usually associated with dredging harbors or channels. Since many spills enter the water environment through small creeks and rivers, it is important to have systems capable of operation in these small tributaries to prevent contamination of major watercourses that are likely to be sources of public drinking water and/or commercial or sport fisheries. A large system that is difficult to transport and requires a time-consuming deployment period would result in spreading the spilled material along the bottom and moving it downstream, thus increasing the area of environmental damage and the volume of contaminated bottom solids that would have to be handled and disposed of. The need for prompt action cannot be stressed too greatly, since removing, processing, and disposing of a small volume of bottom solids with a high contaminant concentration is much less expensive than performing the same operations for a large volume of bottom solids with a relatively low contaminant concentration.

The second characteristic, minimizing physical damage to stream bed and banks, is considered important for two main reasons, cost effectiveness and aesthetics. In most spill incidents, the material spilled does not penetrate the stream bed to depths of more than 6 inches unless too long a period of time is allowed to elapse before cleanup operations are instituted. Removal of more of the stream bed than absolutely necessary, as occurs with large equipment, does nothing to increase efficiency of pollutant removal. It only increases the costs involved. The possibility also exists of altering the ecological and hydrological balance of the area by drastically increasing the depth of the stream channel. In addition, when large equipment is utilized, the inevitable result is either a permanent scar on the stream banks or an expensive re-landscaping cost. For these reasons, it is suggested that large-scale dredging be used in small streams only during special cases where terrain, flow, and other circumstances dictate it to be the only feasible method.

The third characteristic, minimizing resuspension of bottom solids, is vital if downstream water is used for recreation, drinking water, or as a fishery. If the bottom is riled up by removal operations, the spilled hazardous material will be resuspended with the sediment and may enter the water column by dissolution and/or emulsification. Once in the water column, it can be ingested by fish or humans downstream. Resuspension is extremely difficult to control when large-scale equipment is employed, and this is another factor that opts against its use except as a last resort.

From an operational standpoint, the fourth characteristic, a solids/water separation and treatment capability, is vital to any system for removing spilled chemicals from the bottoms of watercourses of any size, large or small. In any conceivable "bottom's" removal system, a large volume of water will, of necessity, enter the system along with the sediment and pollutant. The essential process, from an economic and logistical point of view, is the dewatering of the slurry to reduce its volume. Experience has shown that, on the average, a pumped slurry of mud and water will contain at most 10% solids and at least 90% water. Because, in the case of a spill-contaminated mud, the majority of the spilled material is insoluble in water, and is expected to be bound to the solids, the removal of the associated water, and treatment of it, to an acceptable concentration level of pollutant, will result in a corresponding decrease in the volume of toxic sludge that will have to be disposed of. The transportation of sludge to the disposal site and the handling of the sludge at the spill and disposal sites will become more manageable. For instance, in the case of a cleanup operation that requires a total volume of 500,000 gallons* of slurry (5% solids - 95% water) to be pumped from the bottom of a stream, it would be necessary to transport and dispose of a hundred 5000-gallon tank trucks of waste if no dewatering were possible. If the solids concentration can be increased to 25%, however, the amount of sludge decreases to 100,000 gallons (20 tank trucks) and disposal costs are reduced.

The capability to dewater must, however, include the capability to treat the water removed from the slurry. This is necessary because, even though the material may be relatively insoluble in water, the agitation and turbulence produced in pumping it from the bottom will cause it to be thoroughly mixed with the water and will probably cause dissolution or emulsification of the chemical into the water. The concentrations in question may be low, but may still be above acceptable limits.

Water treatment required may differ depending on the type and physical state of the material involved. For instance, precipitation or ion exchange may be suggested for heavy metal salts, or carbon adsorption for many organics. No matter what the type of contaminant, it will be necessary to make certain that the suspended solids level in the effluent is as low as possible. This is required, not only because the aesthetic quality of water downstream would be damaged by a plume of murky water, but also because there is a high probability that the spilled hazardous material will be associated with the suspended particles, thereby increasing the danger of downstream contamination mentioned previously.

The fifth characteristic, acceptably discharging the effluent, is also important for reasons of aesthetics and water quality. Discharging onto the bank might cause severe erosion and produce an attendant plume of turbidity. The same result would be produced if the effluent was discharged directly into the stream bed at too high a pressure. The real danger, however, would not be the turbidity, but rather the toxicity of the spilled material associated with it.

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* English units of measurement will be used throughout this study when reporting dredging operations since available commercial equipment and dredging operations are commonly described in English units. Conversion factors are included on page x.

The sixth characteristic, an environmentally safe disposal method, is essential if the total problem of removal is to be solved. If the sludge produced from the removal process is dumped at an unapproved landfill or left on the stream's bank, the problem will not be solved but only transferred and deferred to a later date when rainfall may carry it into a stream or percolate it into the groundwater. While it was not the purpose of this study to identify disposal methods per se, a brief investigation of the literature and contacts with EPA's Solid and Hazardous Waste Research Laboratory (SHWRL) at NERC-Cincinnati showed that the disposal method with the widest applicability would be placing the sludge in an approved sanitary landfill. It was recommended that, for the most toxic substances, the sludge should be packaged in sturdy containers such as barrels and shipped to a site where there is little rainfall that might accelerate the corrosion or disintegration of the containers. It is acknowledged that this is not the best conceivable method for disposal of the sludges, but in most cases it is the only method practical at the present time. It should be noted, however, that SHWRL and EPA's Office of Solid Waste Management Programs are studying the problem of toxic and hazardous waste disposal and recommendations for development of future methods are due shortly.

SELECTION OF A TEST SITE

After the system design goals were defined, a search began for a site where such a system could be demonstrated without harm to the environment. Consideration was given to three concepts: (a) a captive site that possessed facilities with flowing streams where actual hazardous materials could be spilled and the entire flow contained and treated; (b) a noncaptive site where an innocuous material, simulating a hazardous material, could be spilled; or (c) a site that was already contaminated by a spill, or repeated spills, of insoluble hazardous materials more dense than water.

By chance, at the same time as the search for a project site was under way, a series of events was transpiring in Milwaukee, Wisconsin, which would have a bearing on the site selection.

On a Saturday morning in June 1971, while participating in a cleanup project sponsored by a local environmental group to remove debris and litter from the Menomonee River, a group of teenagers encountered a sticky, oily substance in the bottom muds of a tributary stream, the Little Menomonee River. Thinking the material to be oil, these young environmentalists did not let it daunt their spirits and continued to remove the dead branches, discarded tires, and similar trash from the river's channel. After a few hours of repeated contact with the material on the bottom, many of the youngsters began to experience a burning, itching sensation on their hands, arms, and legs. The Citizens for Menomonee River Restoration (CMRR), the sponsor of the cleanup, immediately provided first aid, but attempts to wash the substance from the skin of the victims were unsuccessful. Several of the children suffered chemical burns that required hospitalization, and one suffered systemic effects, a kidney malfunction (later attributed to the absorption of the substance through her skin) that necessitated her confinement in a hospital "intensive care unit" for several days.

The incident generated the expected press interest and received national exposure in the media. Public concern was registered immediately and investigations were conducted into the nature and source of this hidden public health menace. The material was determined to be creosote, not waste oil, and was traced to a railroad-tie creosoting operation several miles upstream from the burn site.

The incident and the data concerning the type and extent of pollution was brought to the attention of EPA's Marine and Agricultural Pollution Control Branch of its Office of Research and Monitoring in Washington, DC, who referred the problem to the Hazardous Material Spill Control Research Branch of the Edison Water Quality Research Laboratory at Edison, New Jersey, the very group that was seeking a site for evaluating methods to decontaminate streams polluted by hazardous chemicals more dense than water. A request was made of all 10 EPA Regional Offices to determine if creosote pollution, in general, was a problem of national importance. Although most regions reported scattered creosote spillage incidents, the chronic pollution of stream beds by creosoting operations did not appear to warrant an urgent research project to develop methods to remove the material from industrial effluents, since technology to do this was well within the state of the art. It did appear, however, that existing methods to remove creosote already on the bottom of a stream or river often left much to be desired from an environmental standpoint. These methods consisted of using standard large-scale dredging techniques, such as the dragline or suction dredge, the environmentally objectionable characteristics of which have been discussed previously.

With the information that there were several sites throughout the nation that had been contaminated by creosote spillage, the search for a demonstration site was narrowed to this type of site and captive and noncaptive sites where test spills could be made were no longer considered for the project.

Four of the creosote spill locations appeared to have the appropriate watercourse dimensions and topography, and inquiries were made by the Hazardous Material Spill Control Research Branch of the local government officials involved to determine the availability of these respective streams for this demonstration. These contracts narrowed consideration to only the Little Menomonee River for reasons varying from jurisdictional disputes between some of the localities involved to potential legal problems and the time delays attendant in obtaining permission from the many private and corporate owners of property adjacent to the other candidate streams. The decision to use the Little Menomonee River as the site for the development and demonstration resulted principally because it possessed the following three unique features:

1. The problem of contamination of the stream bottom already existed and the need to spill either an actual or simulated hazardous substance at a captive or noncaptive site was alleviated, thereby resulting in considerable time and cost savings since a hazardous material or simulant did not have to be purchased, nor did a captive site have to be prepared.

2. The Little Menomonee River was a small stream representative of many of the tributary streams that are impacted by spills of hazardous

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materials for which existing bottoms removal (dredging) technology was not applicable.

3. Almost the entire length of the creosote-contaminated section of the river was within the property of the Milwaukee County Parks Commission -- a fact that eliminated any potential jurisdictional or legal problems involved in obtaining permission to work on or near the river and its banks.

PROCUREMENT OF CONTRACTS

After final site approvals were obtained from EPA, the State of Wisconsin Department of Natural Resources, the Milwaukee County Parks Commission, and the Milwaukee County Board of Supervisors, the next step in this project, that of contract procurement, was initiated.

A Request for Proposals (CI-72-0073) was issued for the demonstration of operational systems, with the required design goals, at the creosote-contaminated Little Menomonee River in Milwaukee, Wisconsin. It was the intention of the RFP to select as many systems for Phase I demonstration as could be funded with the $135,000 available. The Phase I field demonstrations would be 10 days in duration and would consist of each contractor utilizing his system to remove the creosote from a separate 500-foot-long segment of the river. A sampling and analysis program for various river water parameters such as DO, pH, TOC, TOD, turbidity, suspended solids, conductivity, ammonia, nitrates, and phosphates, was to be conducted at various intervals upstream of, downstream of, and within the 500-foot segment before, during, and after the Phase I demonstration in order to determine whether the removal operations noticeably upset the stream chemistry. In addition to the above parameters, samples of the bottom mud were taken before, during, and after the demonstration period and were analyzed for creosote content using the method described in Appendix A.

The Phase I removal system that best met the design goals would be selected to perform Phase II, which would consist of the removal of creosote-contaminated mud from the entire contaminated length (approximately 2.5 miles) of the river.

Proposals were received and evaluated by a review panel that met at Edison, New Jersey, and two contractors were selected: Industrial Bio-Test Laboratories, Inc., of Northbrook, Illinois, and Rex Chainbelt, Inc., of Milwaukee, Wisconsin.

ASSIGNMENT OF DATES AND SEGMENTS

After selection of the two contractors, attention turned to the assignment of performance dates and river segments. Several prerequisites were imposed at this point and a logical sequence followed.

The first prerequisite was that each segment be equally accessible. This entailed the use of segments that extended either 500 feet upstream or 500 feet downstream from a road that crossed the stream.

The second prerequisite was that the contractor who was assigned the upstream segment would perform his demonstration first. This was required in order to prevent the possible recontamination of an already cleaned segment, which might occur if the second contractor operated upstream of the first.

After several site visits and visual inspection of river bottom samples, two segments were selected and assigned by a special drawing. The segment beginning at the Bradley Road bridge and extending 500 feet upstream was assigned to Rex Chainbelt, Inc., since its segment was upstream of the other segment. Rex Chainbelt, Inc., was required to conduct its demonstration during the first period, October 2-11, 1972.

Industrial Bio-Test Laboratories, Inc. (IBT) and their subcontractor, R. P. Industries, Inc. (RP) of Marlboro, Massachusetts, were assigned the segment beginning at the Calumet Road bridge and extending 500 feet upstream from that point. IBT and RP were to conduct their demonstration October 16-25, 1972, but due to heavy rains and flooding at the river site during that period, the termination date was extended to November 5, 1972.

The remaining sections of this report detail the activities of EPA and the two contractors in conducting this evaluation of methods to remove spilled hazardous materials from the bottoms of watercourses.

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SECTION 2

CONCLUSIONS

BOTTOMS CLEANUP, GENERAL

1. Spilled insoluble hazardous materials that are more dense than water can be mechanically removed from the bottoms of watercourses by suction dredging.

2. Rapid initiation of bottoms cleanup in a spill-impacted area will minimize the area contaminated by the spill.

3. To reduce the volume of contaminated dredged-spoil that has to be disposed of off-site, dewatering can usually be accomplished on-site by conventional solids concentration technology.

4. Water removed in the solids-concentration process must be analyzed before its return to the stream to assure that it is not contaminated by dissolved or resuspended hazardous material.

5. If the water removed in the solids-concentration process is contaminated, steps must be taken to treat it before its release to the stream.

6. Suction dredging operations on the river had no adverse effect on the quality of the river water.

LITTLE MENOMONEE RIVER CLEANUP

Both the Rexnord (Rex Chainbelt) method and the Industrial Bio-Test Method demonstrated that creosote can be effectively removed from the Little Menomonee River's stream bed.

Concentrations of creosote in the Little Menomonee mud varied from undetectable at some locations to over 20% by dry weight at others.

Despite the fact that the entire bottom of each segment was covered by each contractor, significant concentrations of creosote were detected in the stream bed after each cleanup.

Several areas of the stream's banks were found to be heavily contaminated with creosote.

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Rex Chainbelt Project

The treatment process can be disassembled and loaded for shipping, or unloaded and assembled in one working day.

The floating "river sweeper" developed for picking up bottom muds proved effective. Approximately 12,000 square feet of river bottom were cleaned by the river sweeper and hand-held retriever.

The treatment process utilizing froth flotation, sedimentation, mixed media filtration, and carbon adsorption, removed approximately 99% of the hexane extractables (creosote) and suspended solids in the flow from the retrieval devices. This totaled 1,600 pounds of hexane extractables and 30,000 pounds of suspended solids.

Industrial Bio-Test Project

The treatment process is lightweight and rapidly transportable in modules. Being of modular design, however, several days are required to fully assemble the system in field.

The treatment process utilizing flocculation in a primary settling column, creosote adsorption on powdered carbon in a "Dynactor," coagulation of carbon in a secondary settling column, dewatering of the carbon-sludge in a magnetic separator, and final polishing of the water in a sand filter reduced the creosote concentration from the 200 mg/l range in the system influent to below the detection limit of 0.1 mg/l in the effluent.

Flooding during the demonstration period caused creosote to be redeposited from upstream and from the stream banks into the bed of the demonstration segment.

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SECTION 3

RECOMMENDATIONS

BOTTOMS CLEANUP, GENERAL

To prevent over-dredging and under-dredging of areas, an on-scene analytical capability appropriate to the spilled material should be maintained so that a rapid determination can be made as to whether or not spilled material is present in a cleaned segment.

In flowing watercourses, bottoms cleanup should be initiated at the furthest upstream point where heavy contamination is detection and proceed downstream. Redeposition of contaminant from upstream should, therefore, be minimized.

In non-flowing watercourses, bottoms cleanup should be initiated at the area where heaviest contamination has been detected, to minimize the spread of the spilled material and prevent recontamination of areas already cleaned.

A safe residual concentration should be determined from toxicological data and other factors such as persistence in the environment, location of the spill, and uses of the impacted waterbody.

LITTLE MENOMONEE RIVER CLEANUP

The entire 2.5 miles of contaminated river bottom should be cleaned up utilizing one of the two systems demonstrated during this project.

A maximum permissible level of creosote that can be left in the sediment after cleanup should be established before attempting to remove the creosote remaining in the river.

A rapid spot test should be developed for creosote in the river sediment, so that it can be determined if an area is clean or needs further dredging.

Where high concentrations of creosote are detected in the stream's banks, the Phase II contractor should cut away the banks to ensure that their creosote concentration is below the permissible maximum.

Phase II removal operations should be initiated at Brown Deer Road, the point furthest upstream where significant concentrations of creosote have been detected.

A revised Phase II Project Work Scope should be written to incorporate the above recommendations and should be submitted to the two contractors for rebid. The award of the Phase II contract should be made on the basis of the lower cost.

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SECTION 4

REX CHAINBELT OPERATIONS

DEMONSTRATION SITE DESCRIPTION

The 500-foot section of the Little Menomonee River mandated as the location for demonstration of Rex Chainbelt's system is shown in the aerial photograph, Figure 1. This stretch of the river is bounded on the west by private farmlands, on the east by Milwaukee County parkland, and on the south by

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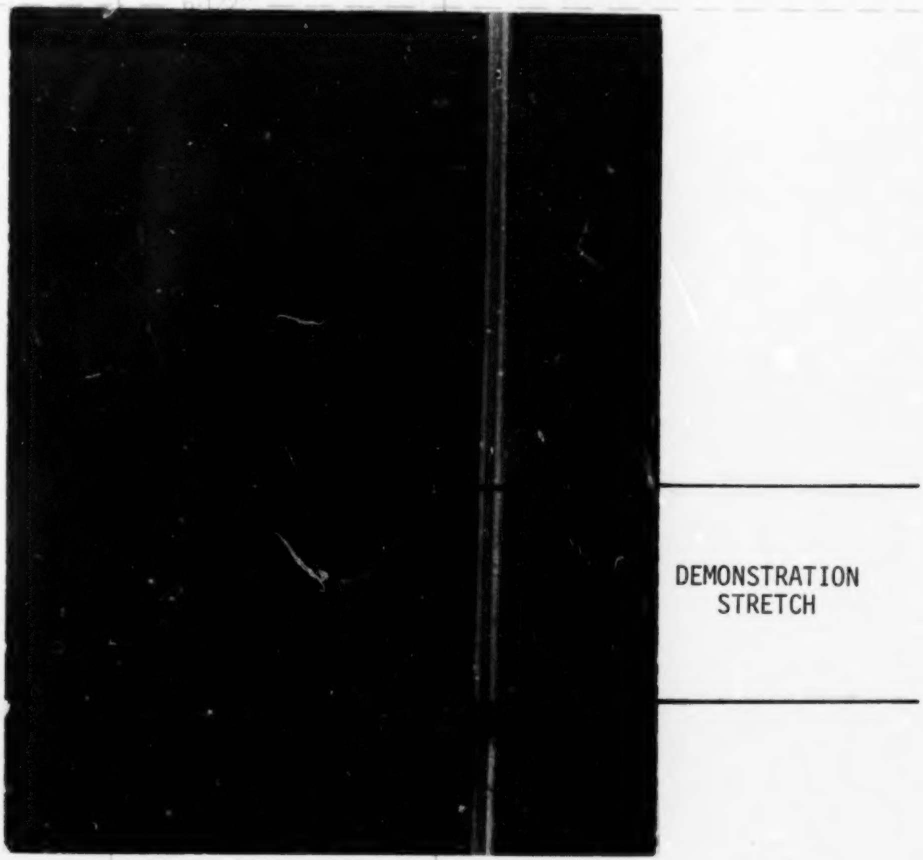

Figure 1. Aerial photograph of demonstration site.

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Bradley Road. Following the river downstream, beginning at the northern limit of the 500-foot stretch, the river heads 10° west of due south for 75 feet. The river then veers sharply to the west, almost paralleling Bradley Road, for 100 feet, then turns in a southwest direction for the remaining 325 feet, until reaching Bradley Road. This 500-foot section has an east-west linear displacement of 350 feet and a north-south linear displacement of 400 feet. A survey of the river taken on September 25, 1972, showed the width of the river in this stretch to vary from a minimum of 12 feet to a maximum of 30 feet, with a mean width of 21.6 feet. The width measurements were taken at 25-foot intervals along the entire 500-foot stretch. These measurements, when transferred to working paper and planimetered, result in an estimated river bottom area of 12,040 square feet. Because of the extremely high amount of rainfall during August and September, the river at this time was much wider than during normal months of precipitation.

Cross-section depth profiles taken at the time of the width survey showed the river bottom to drop off very sharply within 2 feet of the shore and then slope mildly to the middle of the river. The mean depth at the middle of the river was 2.75 feet, with a range of 2.0 to 5.0 feet. The last 200 feet on the downstream end of the section was shallower than the upstream 300 feet, having a mean depth of 2.18 feet compared with 3.13 feet upstream. The maximum depth of the river occurs under a railroad trestle that crosses the river between 325 feet and 350 feet upstream of Bradley Road. This trestle has three concrete supporting structures, each 24 inches wide and 15 feet long, channelling the river into three separate streams at this location. The river reaches a width of 28 feet at this point.

The entire 500-foot stretch of the river is bounded on both shores by very dense trees, bushes, and other natural vegetation, making it very difficult to visually locate the river from more than 50 feet away from either shore. The terrain of both the east and west sides of the river contains high, uncut grasses, and is very soft, with standing water of up to 3 inches making it impossible for the ground to support any excessive weight. Figure 2 is representative of the river along the demonstration stretch. Bradley Road, the southern or downstream limit of the 500-foot section, is a two-lane, asphalt-surfaced road with very little vehicular traffic. A gravel shoulder varying from 5 to 10 feet in width is located on the north side of the road.

RETRIEVAL AND TREATMENT PROCESSES DESIGN

Successful removal of the river bottom muds and associated contaminants as well as production of a high-quality system effluent for return to the river required the development of three distinct unit operations. These included: (1) the development of a retrieval device that could physically withdraw bottom muds up to 3 feet deep at a rate high enough to be economically feasible, (2) the design of a solids/liquid transport system that would have the capability of conveying the bottom muds from the retrieval device to the treatment process, and (3) the modification of existing mobile treatment vehicles, capable of achieving a high degree of treatment efficiency on the contaminated muds, for this specific use.

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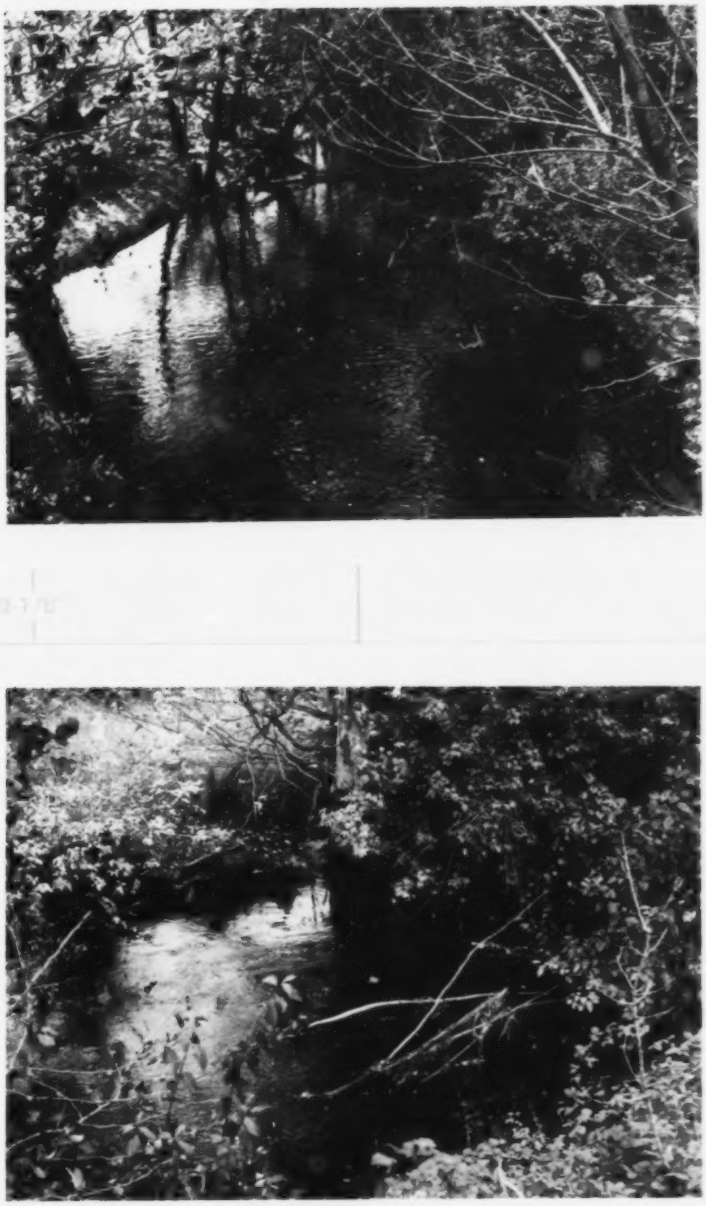

Figure 2. Typical segments of demonstration stretch.

Retrieval Device

The criteria used in the design of the retrieval device included the ability to operate in all sections of the river regardless of width, sufficient capacity to produce high flowrates and cover large areas quickly, and adequate mobility to allow access to all areas of the river.

The retrieval vehicle ultimately designed and fabricated is pictured in Figure 3. The device ("River Sweeper") is essentially a floating, pontoon-supported chassis, containing a suction line (mast) that is hydraulically powered to move simultaneously in three dimensions, along with an operator's chair and control instruments. The suction line consists of 3-inch, thin-walled steel tubing with a 16-inch-diameter circular spun aluminum suction head attached to the bottom end. The suction head, which is 3.5 inches deep, has 10 water knives spaced around its inner periphery. The purpose of these knives is to "cut" or "loosen" bottom muds that are too viscous to be vacuum-pumped. This suction head is illustrated in Figure 4. The flow through these knives is recycled water from the sedimentation tank used in the treatment process. The suction line, which terminates at the top of the mast, is connected to 3-inch flexible rubber hosing that leads to a suction pump located on shore. (Pumps and hosing are discussed later in this section.) The suction head can be extended 4.5 feet below the water surface, and provisions have been made to allow greater depths to be achieved by adding extensions in deeper water. Complete specifications of the "River Sweeper" are listed below.

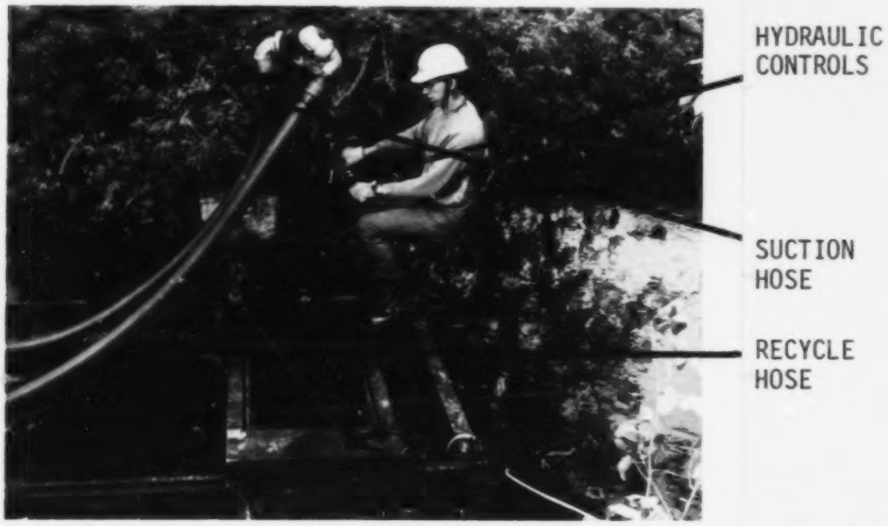

Figure 3. River Sweeper retrieval device, Rex Chainbelt.

Structural Material:	Aluminum
Width:	8 feet
Length:	12 feet
Weight:	900 pounds
Buoyancy:	2000 pounds
Cleaning Area:	50 square feet (per setup)
Suction Line:	3-inch thin-wall steel
Recycle Line:	(2) 1.25-inch thin-wall steel lines
Power Supply:	Hydraulic (oil)
Hydraulic Operating Pressure:	700-1000 psi
Mast Speeds:	
Fore-Aft	20 ft/min.
Medial-Lateral	20 ft/min.
Vertical	20 ft/min.

The River Sweeper contains four manually driven spuds, one located on each corner of the vehicle to provide horizontal stability against river currents. These spuds are 6 feet long, with 3-inch-diameter hollow aluminum tubes with pointed ends on the bottom. When the vehicle is located at a position ready for cleaning, the spuds are cranked down into the river bottom. Upon completion of cleaning the designated area, the spuds are raised and the vehicle is moved to a new location. The vehicle can be moved in shallow water by pushing it from place to place, and in deeper water by attaching a tow rope to the vehicle frame.

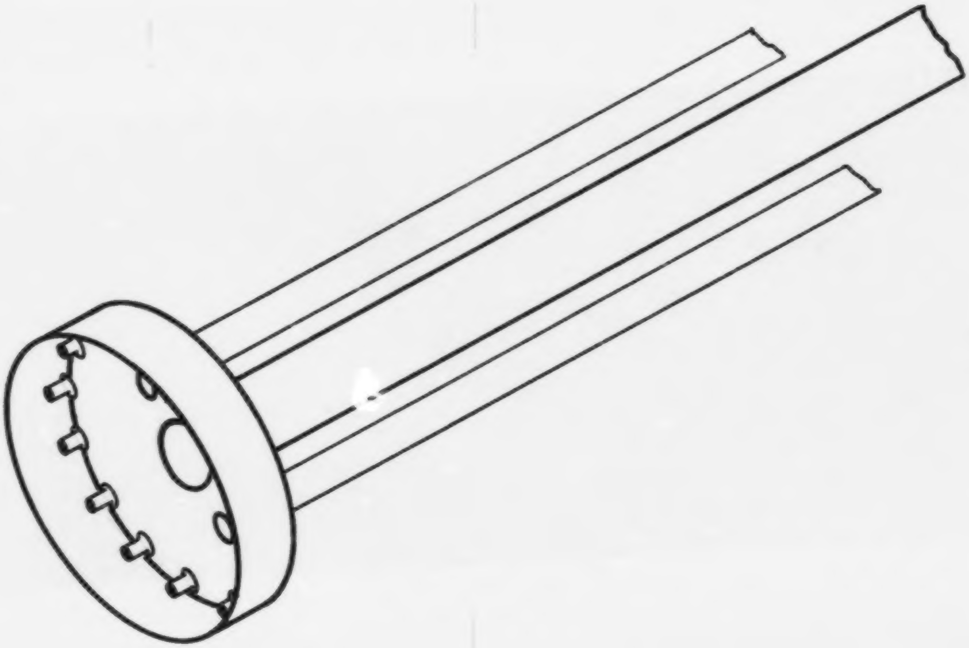

Figure 4. River Sweeper suction head.

Because the many irregularities of the shoreline and the many trees and other obstructions in the river made these areas inaccessible to the River Sweeper, it was necessary to fabricate a small, hand-held suction device for cleaning these areas. This device is shown in Figure 5. The suction head is 9 inches in diameter and 3 inches deep. The suction head is connected to a 4-foot-long, 3-inch-diameter aluminum shaft. Three-inch hose connects the shaft to its pump.

Solids/Liquid Transport

A pickup rate of 100 gallons per minute was chosen as the design rate for the transport system. It was felt that this rate was needed in order to thoroughly clean a 500-foot stretch properly in 10 days. The size of hoses and pumps needed for rates higher than 100 gpm would be too large for use as a portable system. Since it was not known during the design phase which 500-foot section of the 2.5-mile stretch would be chosen for the system demonstration, the design of the solids/liquid transport system was completed assuming that the distance between the farthest point of pickup in the river and the treatment process could have been up to 500 feet, and that vertical lift between the river and treatment process could have been up to 20 feet. Based upon samples of the river bottom taken along the entire 2.5-mile stretch, it was also determined that it would be necessary to pump a fluid with up to 10% solids by weight, and that it could be expected that many rocks, twigs, leaves, etc. would be picked up with the river muds. The pumps chosen to be used had to apply the suction or vacuum to the river muds, pick up these muds, and then transport them up to 500 feet to the treatment process.

The pump chosen to work with the River Sweeper device was a HYDR-O-MATIC, 4-inch centrifugal trash pump manufactured by the Hydr-O-Matic Pump Company of Hayesville, Ohio. This self-priming pump, Model No. 40EP-VH4DWA,

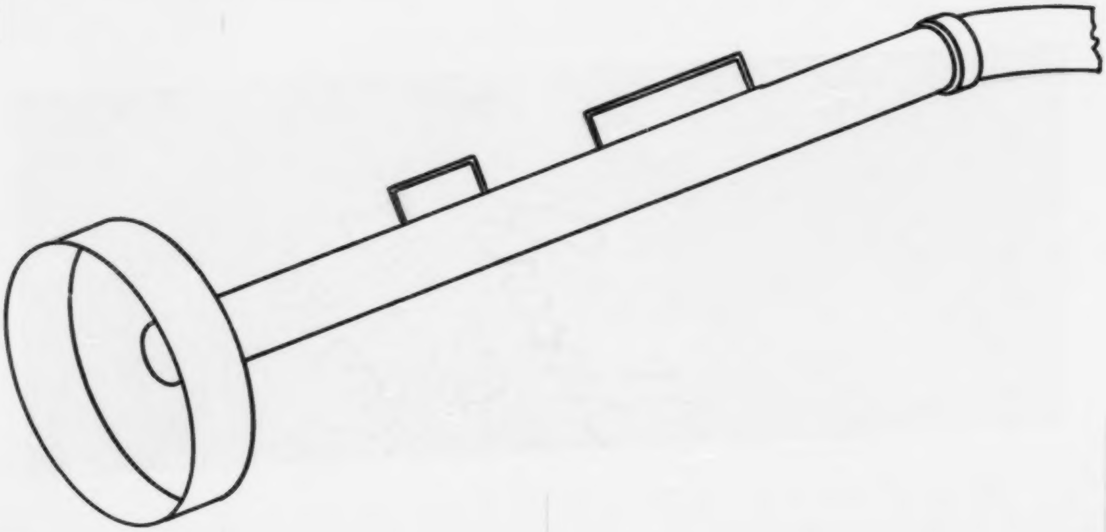

Figure 5. Hand-held retrieval device.

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is wheel-mounted and powered by a 30-horsepower gasoline engine. The pump has a total head of 145 feet at a 100-gpm flow, with a suction lift of 25 feet and the ability to pass 3-inch solids. The pump chosen to work with the hand-held pickup device was purchased from the same vendor and is a HYDR-O-MATIC, 3-inch centrifugal trash pump Model No. 39EP-AGNDW. THis pump is wheel-mounted, powered by a 12-horsepower gasoline engine, and has a total head of 120 feet at 100 gpm. The pump is self-priming, has a 25-foot suction lift, and will pass 1.75-inch solids. The 4-inch pump is shown in Figure 6.

Three-inch hose was used to connect the River Sweeper suction line and hand-held device to pumps, and also to connect the pumps to the treatment process. Hard-wall rubber hose was used on the entire length of the suction side of each pump and for 50 feet on the discharge side, the remainder of the hose being common 3-inch mill hose. All hose connections were of the quick-disconnect type so that sections could be added, removed, or cleaned out very quickly. A 100-gpm flow through the 3-inch-diameter hose has a velocity of 3 to 5 feet per second, which was deemed sufficient to prevent solids deposition in the lines.

Provisions were also made for using the cutting knives on the River Sweeper suction head if their use became necessary. A 200-gpm submersible pump and a 200-gpm booster pump, along with appropriate hose, were available to pump supernatant from the sedimentation tank used in the treatment process back to the suction head.

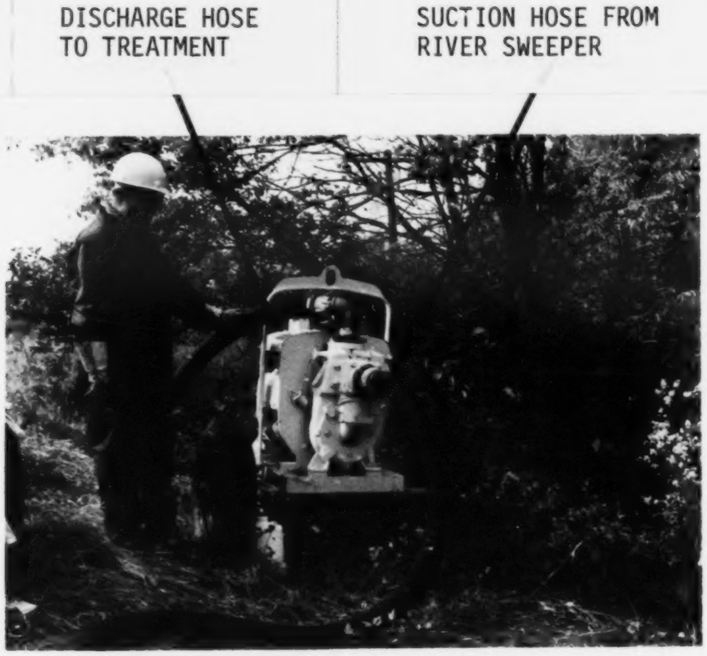

Figure 6. Four-inch suction pump in use.

Treatment Process

The treatment system used to separate the contaminated river muds from the aggregate pumped from the river bottom, dewater the mud, and to purify the water removed before returning it to the river consisted of four separate devices: (1) a froth flotation unit, (2) a hydrocyclone, (3) a sedimentation tank, and (4) the Mobile Hazardous Spills Treatment Trailer. A block diagram of the entire treatment process is shown in Figure 7.

Froth Flotation--

A froth flotation unit was used as the initial step in the treatment of the raw flow to remove the free or loosely bound creosote from the river muds before further treatment. The Mobile Beach Cleaner developed by Meloy Laboratories of Springfield, Virginia, under EPA Contract 14-12-809 is pictured in Figure 8. This vehicle, initially developed for the purpose of removing oil from beach sand following an oil spill, consists of a feed hopper for entry of the contaminated sand, four froth flotation cells in series, a supercharger for air, and a diesel generator. The entire unit is mounted on a 40-foot by 8-foot truck-trailer. The unit is shown schematically in Figure 9.

Since this application consisted of the treatment of an already mixed solid/liquid flow, the feed hopper was not needed. Instead, the raw flow emanating from the mill hose was piped through a butterfly throttling valve and Venturi flow meter into the first flotation cell. Since the bottom muds were to be ultimately hauled to a landfill, the purpose of this treatment was not to completely remove all the creosote present, but rather to remove the free creosote which could be detrimental to the later liquid treatment processes and equipment. The creosote and other contaminants buoyed to the water surface in the flotation cells were skimmed into an exit trough and piped to a small storage tank. A view of the flotation cells and the rotating paddles used for skimming are shown in Figure 10. The liquid effluent from the flotation unit was pumped directly to the hydrocyclone. This pump was located on the ground next to the flotation unit trailer. The hydrocyclone was built on a supporting stand on the trailer and located between the flotation units and the diesel generator.

Hydrocyclone--

The hydrocyclone is a commercially available model manufactured by Rex Chainbelt Inc., Milwaukee, Wisconsin. The 1-foot-diameter hydrocyclone was fitted with a 4-inch vortex discharge orifice and a 2-inch apex discharge orifice. The pump was set at a constant rate of 300 gpm. This is the minimum flowrate at which this particular hydrocyclone is effective in classification of materials. In order to maintain a minimum flow of 300 gpm through the hydrocyclone, a recycle loop was constructed, with the flow through this loop throttled so that it could be changed with a change in the flowrate through the flotation cells, always keeping a minimum flow of 300 gpm through the hydrocyclone. The purpose of the hydrocyclone was to separate heavier materials such as gravel, rocks, and sand from the flow going to the following sedimentation tank, and thus preventing an excessive buildup of sludge, or the formation of a sludge that could not be pumped from the sedimentation tank. This discharge flow was designed to be approximately 3% of the flow through the hydrocyclone. A header was constructed to carry this flow from the apex of

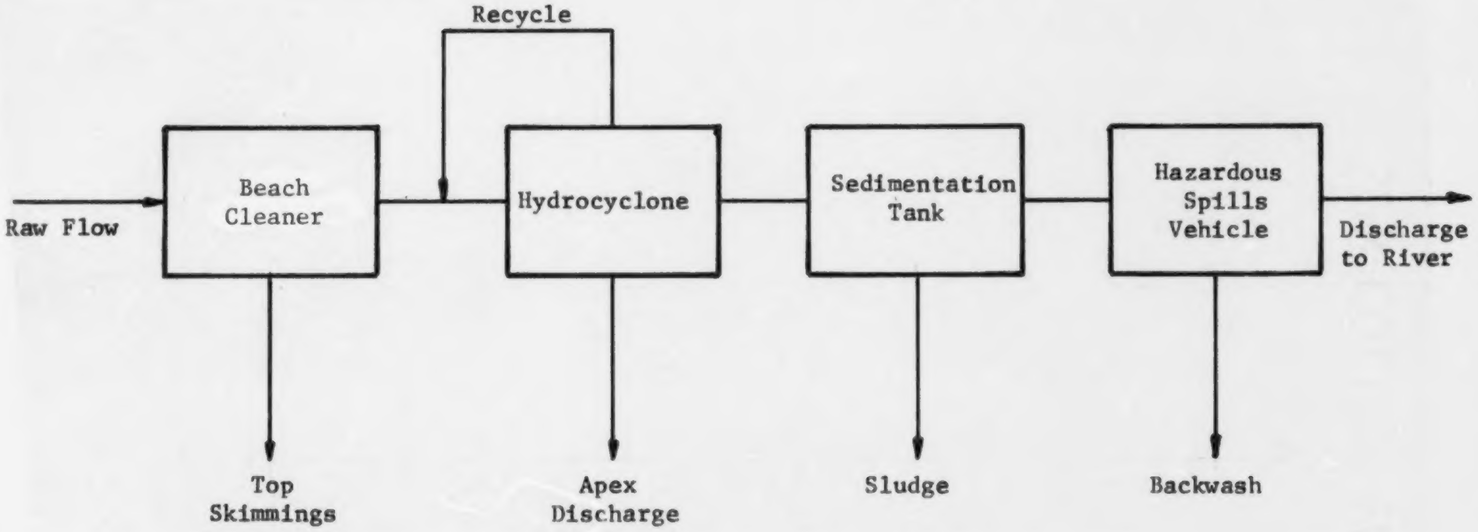
Recycle
Raw Flow
Beach Cleaner
Hydrocyclone
Sedimentation Tank
Hazardous Spills Vehicle
Discharge to River
Top Skimmings
Apex Discharge
Sludge
Backwash

Figure 7. Block diagram of Rex Chainbelt treatment process.

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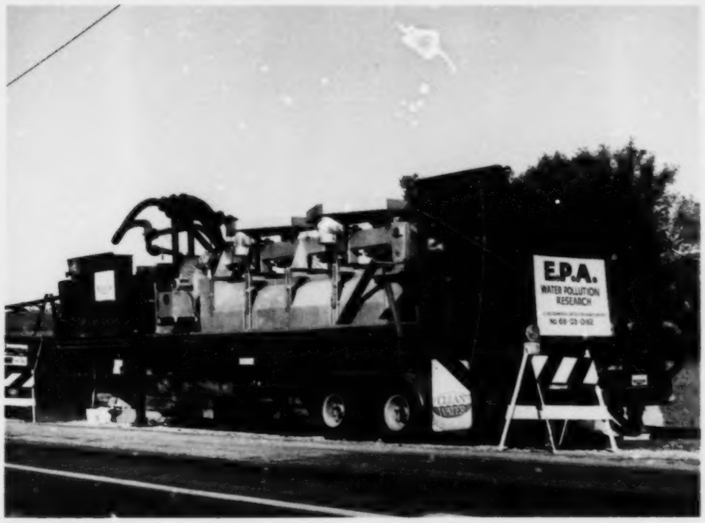

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WATER POLLUTION RESEARCH

Figure 8. Photograph of EPA mobile beach cleaner.

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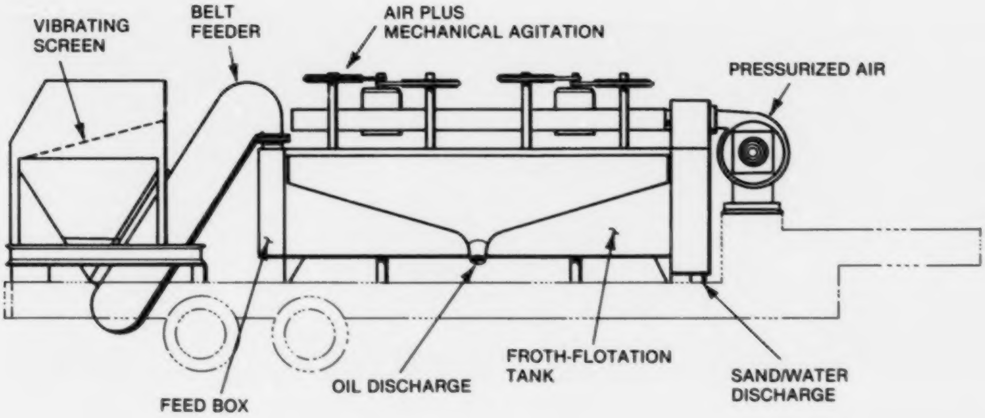

VIBRATING SCREEN
BELT FEEDER
AIR PLUS MECHANICAL AGITATION
PRESSURIZED AIR
FEED BOX
OIL DISCHARGE
FROTH-FLOTATION TANK
SAND/WATER DISCHARGE

Figure 9. Schematic of beach cleaner vehicle.

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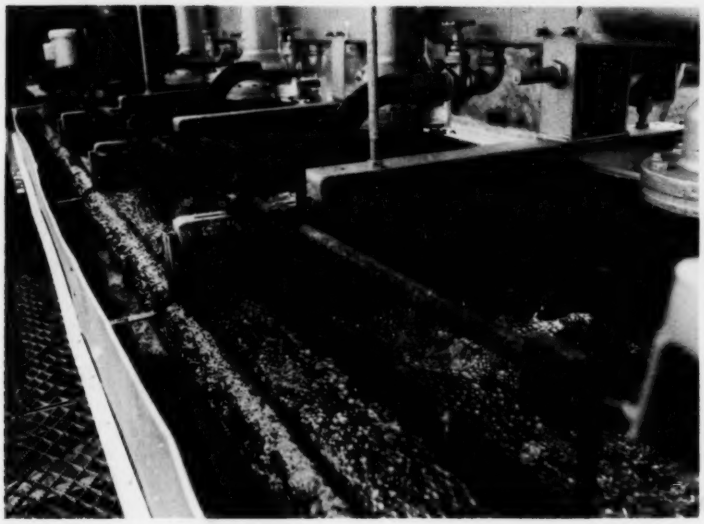

Figure 10. Flotation cells and skimmers in use.

the hydrocyclone to 12-cubic-yard dumpsters located beneath the header.

Flow to the sedimentation tank from the hydrocyclone was throttled by a butterfly valve and measured by a Venturi meter. Under normal operating conditions, this flowrate was the same as the raw flow to the flotation cells. By keeping this flow equal to the flow coming into the flotation cells, it was possible to keep a constant level in the flotation cells. This level is mandated by the depth of creosote forming on the top of the water surface necessitating skimming. Flow to the sedimentation tank was carried by 3-inch rubber hosing and discharged directly into the center of the tank.

Sedimentation--

The sedimentation tank was part of the equipment supplied with the Hazardous Spills Vehicle, which was developed for EPA by Rex Chainbelt Inc., under Contract 68-01-0099. This portable tank is constructed out of rubber and can be set up in the field in less than 2 hours by three men. The tank, shown in Figure 11, actually consists of two concentric tanks. The inner tank is 4.5 feet deep and 11 feet 3 inches in diameter, with 19 four-inch-diameter orifices located around the periphery of the tank, 11 inches below the top. The outer tank is 25 feet in diameter, and is also 4.5 feet high. The inner tank, which is used as a flocculation chamber, has a volume of 3360 gallons. The outer tank has a volume of 13,180 gallons, making the total volume of both tanks 16,540 gallons.

The sedimentation tank was originally designed for coagulant addition and settling on a continuous basis. However, for this specific application it was decided to use the tank on a batch basis. It was expected that flow to the tank would be discontinuous due to the moving of the retrieval vehicle from one location to another, and to the short periods of down-time that would occur

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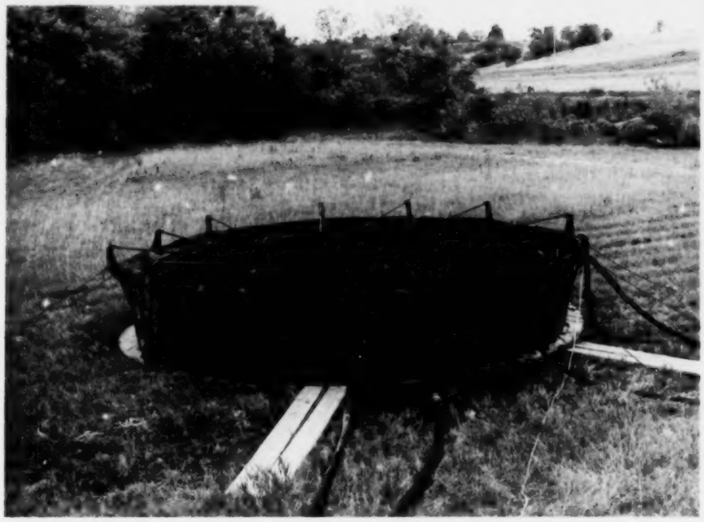

Figure 11. Portable rubber sedimentation tank.

if the retrieval vehicle became clogged. The flowrate to the treatment system was also expected to fluctuate, depending upon whether both or just one of the retrieval devices were being operated. Coagulant addition was accomplished by running a 4-inch hose line from the outer portion of the sedimentation tank up to the suction end of the 350-gpm backwash pump on the Hazardous Spills Vehicle. The discharge end of this pump was connected by hose to a flow header shown in Figure 12. Coagulant was added at this location by means of a BIF Model 1271-23-9121 chemical feed pump and the flowrate measured. A small in-line cyclone mixer was used for coagulant dispersion. The flow from this header was connected by hose to an opening on the bottom of the inner sedimentation tank. By this means the flow continued in a closed loop until all the coagulant had been added. After this was completed, the liquid was allowed to settle before further treatment.

Mobile Hazardous Spills Treatment Trailer--

The Mobile Hazardous Spills Treatment Trailer was designed as a rapidly deployable system to respond to and treat spills of organic and inorganic water-soluble substances. This vehicle, developed for EPA under Contract 68-01-0099, is shown in Figure 13. The portable sedimentation tank, described previously, is stored on the trailer deck during transport and set up in the proximity of the vehicle at the site of the spill. The major components of this vehicle include the capability for addition of chemicals for coagulation and pH adjustment, followed by mixed media filtration and carbon adsorption. A block diagram showing the process flow is shown in Figure 14.

The mixed media filtration process consists of three pressure filtration columns, operated in parallel. The columns, flakeglass-lined steel pressure vessels, are each 42 inches in diameter and 80 inches high, and contain 18 inches of common red flint sand having an effective size of 0.5 mm and a

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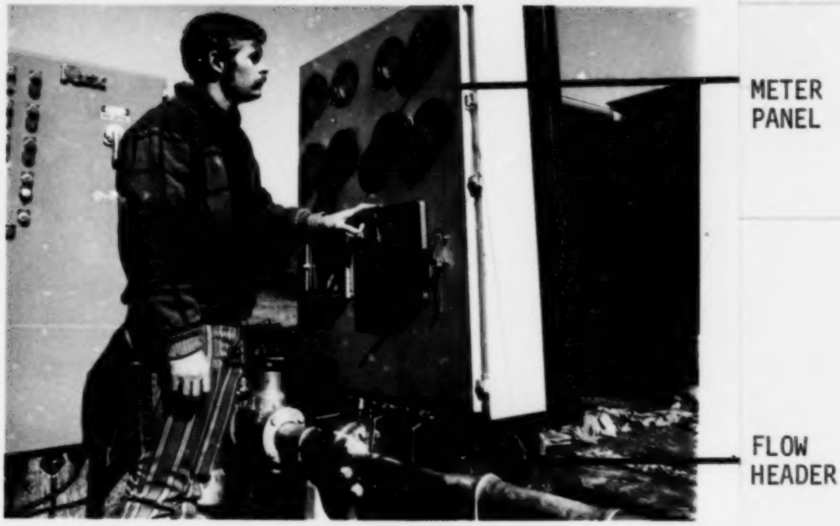

Figure 12. Meter panel and flow header.

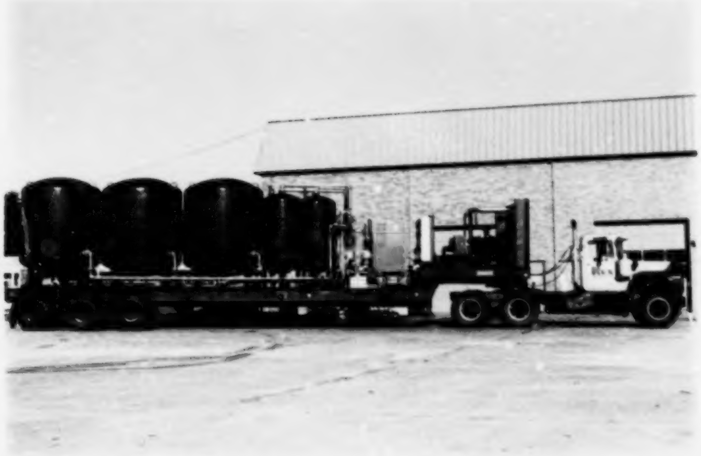

Figure 13. Mobile hazardous spills treatment trailer.

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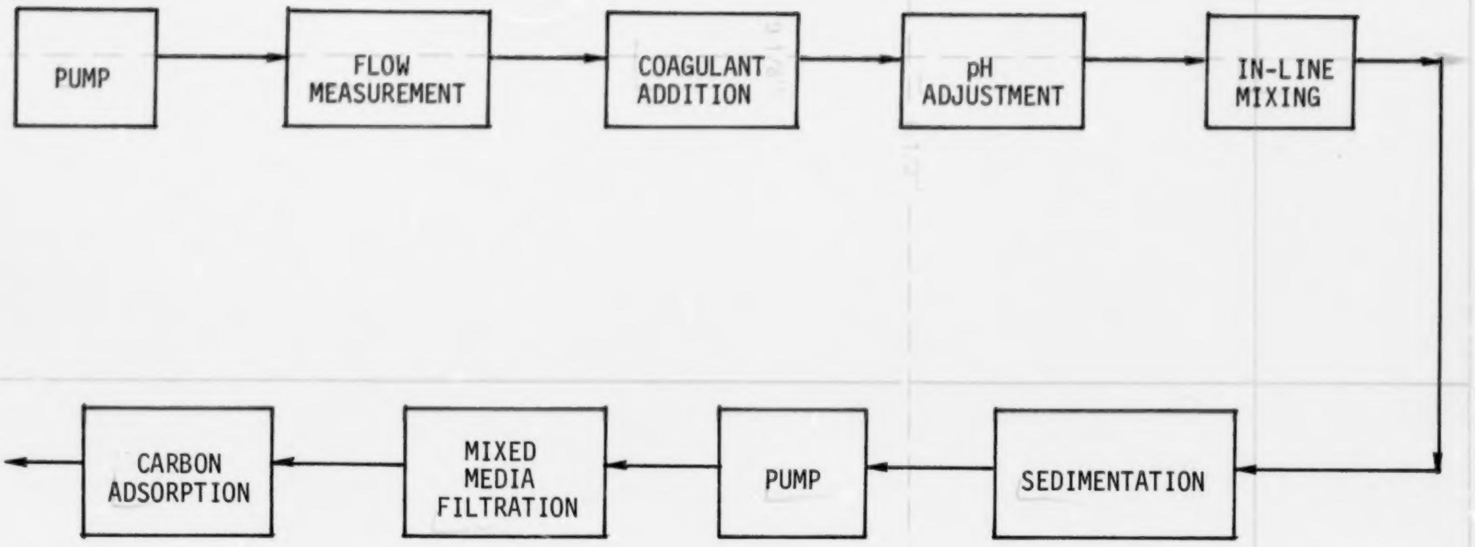
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FLOW MEASUREMENT
COAGULANT ADDITION
pH ADJUSTMENT
IN-LINE MIXING
SEDIMENTATION
PUMP
MIXED MEDIA FILTRATION
CARBON ADSORPTION

Figure 14. Block diagram of hazardous spills vehicle flow.

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uniformity coefficient of 1.5 beneath 24 inches of anthracite (Anthrafilt No. 1-1/2) with a standard size of 0.85 and 0.95 mm. The total surface area of the three columns is 28.8 square feet.

Carbon adsorption is accomplished in three columns that can be operated either in parallel or in series. These columns, 83 inches in diameter by 105 inches high, are also flakeglass-lined steel pressure vessels. For use on this project, only one carbon column was filled with carbon and used. The column was filled with 6000 pounds of 18 x 40-mesh Witco Grade 718 activated carbon. The wetted volume of carbon was estimated to be 230 cubic feet. A closeup view of the mixed media and carbon columns is shown in Figure 15.

Three portable rubber pillow tanks are also part of this vehicle. These tanks are 12 feet by 12 feet and have a volume of 3000 gallons. The purpose of these tanks is to store sludge from the sedimentation tank and to hold a supply of backwash water for the mixed media and carbon columns. The system is designed to be backwashed with the wash water going back to the sedimentation tanks, where the solids are settled out and handled with the normal sludge. In the application on the Little Menomonee River, two of the pillow tanks were used, one to store carbon column effluent for backwash, the other to store the creosote removed during froth flotation. The sludge from the sedimentation tank was pumped directly from the tank to a commercial liquid hauler who deposited the sludge in a landfill approved by the Wisconsin Department of Natural Resources.

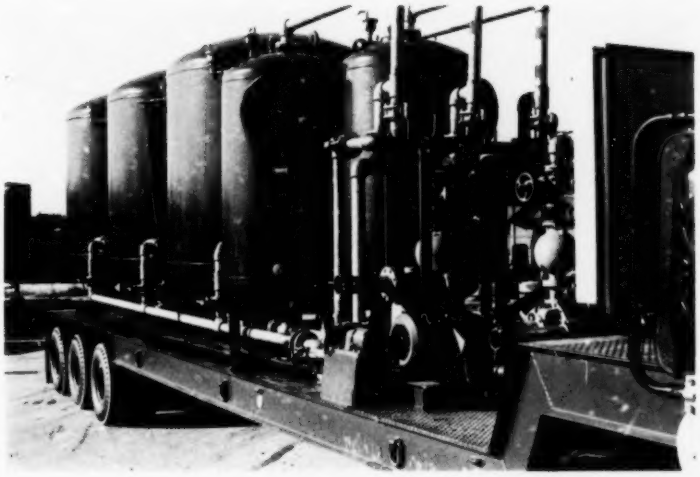

Figure 15. Mixed media and carbon columns.

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FIELD DEMONSTRATION

Preparation

A very limited amount of time was available for testing the various unit operations of the system before actual operation at the project site. Since fabrication of the River Sweeper retrieval device and the mobile hazardous spills treatment trailer was not completed until the week before the system was to be used on the Little Menomonee, it was not possible to test this equipment completely before actual use. However, a hydraulic test was run on the froth flotation unit at the Rex Chainbelt facility in the following manner. The rubber sedimentation tank was set up and filled with city tap water for use as a water source for the froth flotation unit. In order to simulate actual field conditions, the 4-inch centrifugal pump and hydrocyclone were also used. Water was pumped by the 4-inch pump into the flotation cells and then through the hydrocyclone and back to the sedimentation tank, forming a closed loop, thereby testing all the piping and flow meters along with the output of the generators on both the froth flotation unit and on the hazardous spills vehicle. (The generator on the hazardous spills vehicle was used as the electrical supply source for the hydrocyclone pump.) After completing this test, all the equipment was packed on two flatbed trucks and the froth flotation vehicle and hazardous spills vehicle were readied for shipment to the Little Menomonee River on Monday morning, October 2, as directed by EPA personnel.

Plan of Operation

The plan of operation called for using the first of the 10 days allowed for the process demonstration as the time for unloading and erecting all equipment at the project site. The following 8 days were to be used for river cleanup with the tenth or last day to be used for disassembly and packing of the equipment for removal from the site.

The plan for river cleanup and treatment process operation divided the work day into two identical segments. The first (morning) segment would consist of operating the retrieval equipment, flotation unit, and hydrocyclone, until the sedimentation tank was full. It was estimated that this would take at least 4 hours, since the retrieval vehicles would actually be picking up bottom muds only half of the time while being operated. The remainder of the time would be spent in moving the vehicles and equipment and in system maintenance. Once the tank was full, coagulant addition would begin, followed by settling and then processing through the hazardous spills vehicle. While this operation was occurring, the personnel associated with the operation of the retrieval devices and froth flotation vehicle would take their lunch break, and then move the pumps and hoses to the location of the second (afternoon) segment of pickup operations. The afternoon would be the same as the morning, except that instead of taking a lunch period, the operating personnel on the retrieval devices and froth flotation vehicle would retire for the day. Those persons associated with operating the hazardous spills vehicle would remain for the evening until the liquid in the sedimentation tank had been processed.

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No minimum or maximum number of feet were set as a guideline to be accomplished in one day. This would have been impossible, since this was the first time this system was used and no one could predict any feasible rate of progress. Instead, it was decided to work as long as daylight hours permitted, or until the sedimentation tank was full in the afternoon. It was assumed that the latter would be the governing factor.

In keeping with the system design goals of disturbing the surrounding environment as little as possible, much care was taken in choosing the location for the treatment equipment. Originally it was thought that all equipment would be located on the parkland along the east shore of the river. However, this was not possible since the soft, wet ground in this area would be torn up by the two large treatment vehicles. As a result, it was decided to locate the vehicles on the shoulder of Bradley Road with the sedimentation tank, pillow tanks, and skimmings tank placed on the parkland itself. (Permits for use of the shoulder were received from the City of Milwaukee and the site was approved by the City Traffic Engineer's Office.) Figure 16 shows a schematic diagram of the final plan for equipment location.

Choice of Coagulant

Samples of bottom muds taken on August 30 in the designated 500-foot stretch were used for determination of an effective coagulant in the sedimentation process. The river muds were diluted 1 to 15, approximating the concentration that would be seen in the sedimentation tank. The samples were allowed to settle for 1.5 hours, simulating the settling period in the sedimentation tank before coagulant addition. Following this, the supernatant was drawn off and tested with various chemicals and polymers at different concentrations. The effectiveness of the coagulant was based upon visual clarity and rapidity of floc formation.

The coagulant that formed the best floc and most enhanced the settling rate was ferric chloride ($FeCl_3$). It was found that this coagulant was effective with concentrations of up to 150 mg/liter. It was also felt that the concentrations of $FeCl_3$ needed would be advantageous over other coagulants since the smaller liquid volume of coagulant needed would be easily transportable and stored. It was also noted that a cationic polyelectrolyte, Calgon 105C, improved the floc formation when added in concentrations of 0.5 mg/liter with the $FeCl_3$. However, it was felt that the degree of clarity achieved by addition of this polyelectrolyte was not needed because of the high degree of treatment following this step. It was planned to use $FeCl_3$ at a concentration of 50 mg/liter initially, and increase the concentration if warranted in the field.

Field Development

On Monday, October 2, all equipment was shipped to the site, unloaded, and deployed. A commercial cartage firm was hired to supply a tractor for hauling the beach cleaner and mobile hazardous spills treatment trailer to and from the project site and a hydraulic crane truck was rented for unloading the heavy equipment, including the pumps, piping, retrieval devices, hydraulic power package, and hoses. Because of the sloping shoulder of the road, lumber

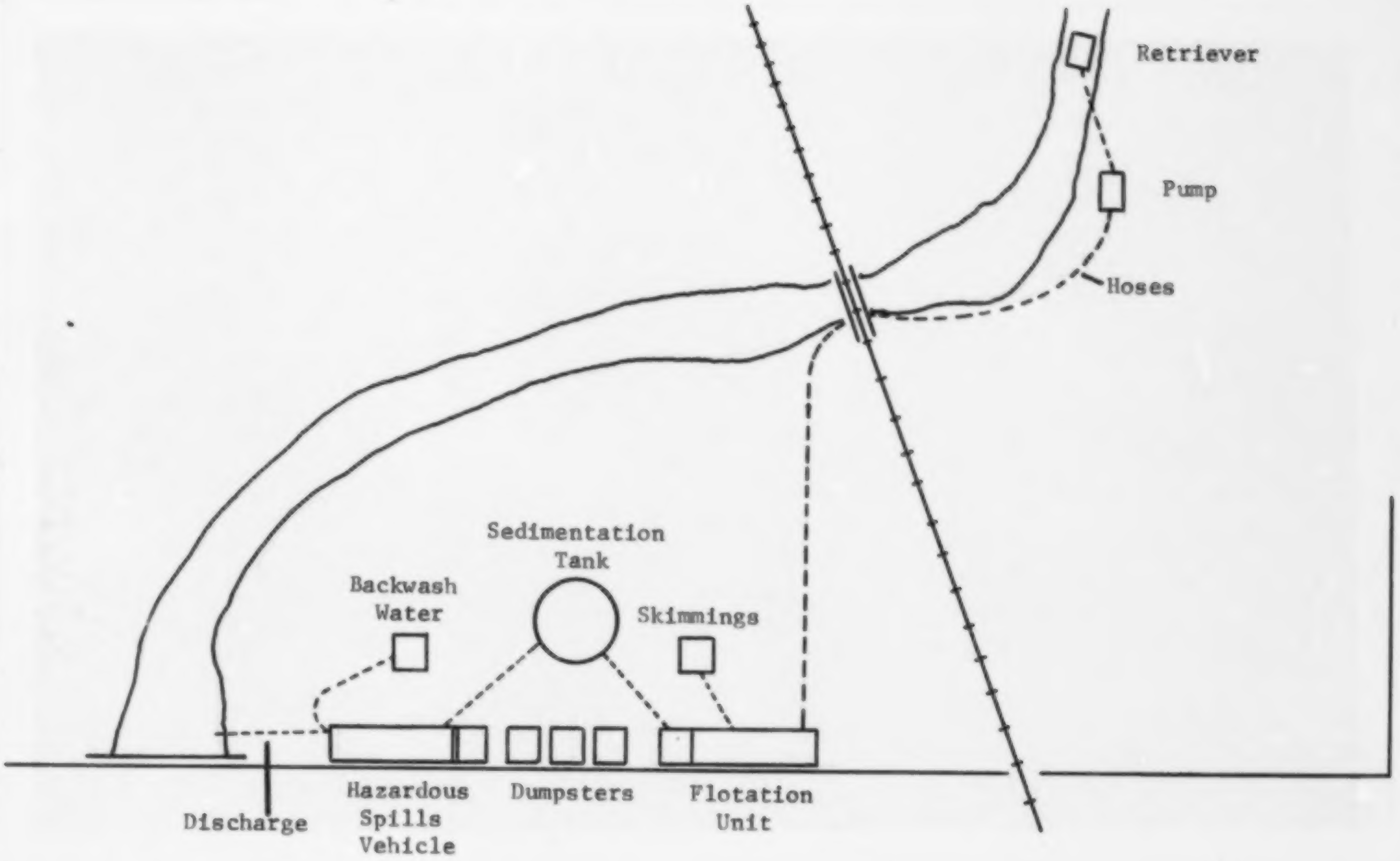
Retriever
Pump
Hoses
Sedimentation Tank
Backwash Water
Skimmings
Hazardous Spills Vehicle
Dumpsters
Flotation Unit
Discharge

Figure 16. Schematic view of field setup.

platforms were placed under the wheels to level the treatment vehicles. A view from the river looking up to the treatment process is seen in Figure 17. The white lines in the foreground are the hoses leading from the river to the froth flotation vehicle in the left of the picture. A view of the treatment vehicles taken from Bradley Road is seen in Figure 18.

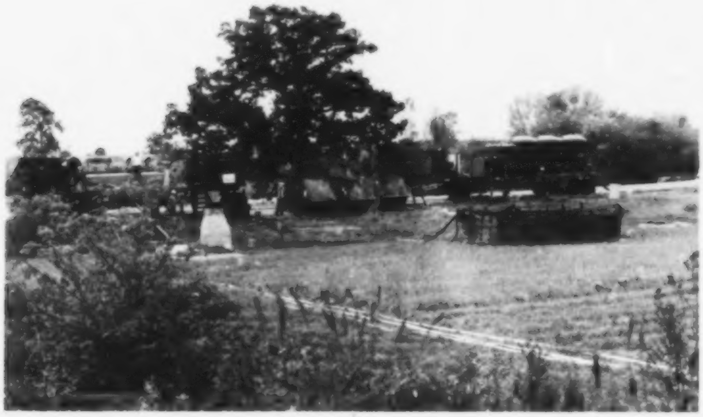

Figure 17. View of Rex Chainbelt treatment process from river.

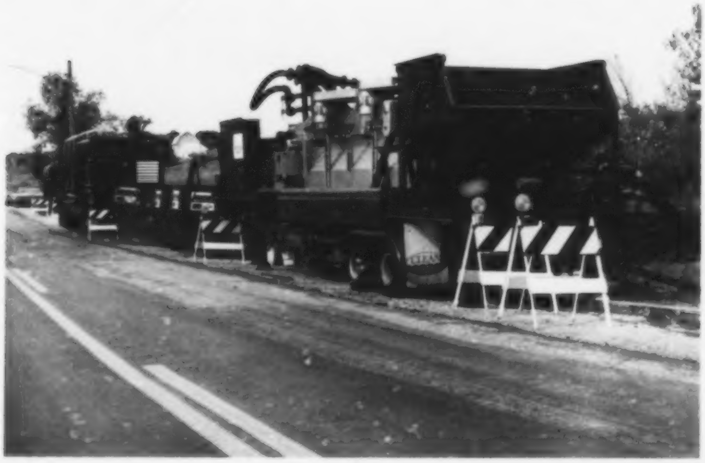

Figure 18. View of Rex Chainbelt treatment process from Bradley Road.

The River Sweeper was launched at the 500-foot mark upstream and all pumps, hoses, and piping were connected. An absorbent boom for containing the oil and creosote dislodged from the bottom muds and buoyed to the surface during pickup operations was constructed at the Bradley Road bridge. The boom, Model 12D, manufactured by Colloid Chemical Company of Brockton, Massachusetts, is 12 inches in diameter, and is filled with an inert oil absorbent material. Straw was placed in front of the boom to help contain and absorb the floating oil and creosote. The boom is pictured in Figure 19. By the end of the day, the entire system was deployed and ready for operation the following morning.

System Operation

Actual pickup and treatment operations began on Tuesday, October 3. The majority of the day was spent in system shakedown and in developing a knowledge of equipment operating characteristics and capabilities, but 20 linear feet of river were cleaned during the day. A total of 16,000 gallons was pumped from the River Sweeper to the treatment process. However, due to the operator acquainting himself with the operation of the retrieval vehicle, this flow contained mostly river water with little bottom mud. The beach cleaner operation was trouble-free, with the operator of this vehicle being able to quickly develop the technique of holding a constant level in the cells by controlling the raw flow and hydrocyclone discharge by the throttle valves. A small backyard wading pool was used as a reservoir to contain the top skimmings from the froth flotation units. When filled, its contents were pumped to the pillow tank located directly behind it. The top skimmings discharge line from the flotation units, the small wading pool, and the pillow tank can be seen in Figure 20. The skimmings from the flotation discharge flowed by gravity.

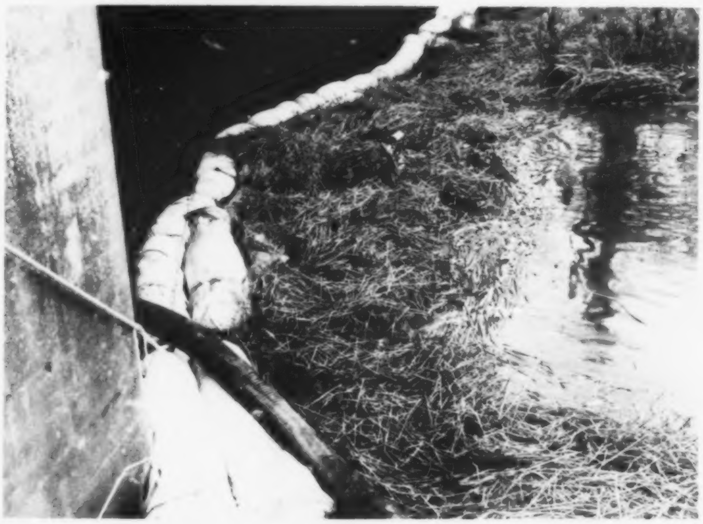

Figure 19. Oil boom in use.

The Hazardous Spills Vehicle was used during this evening for the first time and operated successfully, treating 15,000 gallons of liquid from the sedimentation tank. Complete details of the treatment process operation and effectiveness are discussed in the next section. The effluent from the carbon columns discharged by gravity through a 4-inch hose terminating in the river under the Bradley Road bridge.

On Wednesday, October 4, the second day of cleanup operations, 40 linear feet of river were cleaned. A great deal of time was lost due to problems in starting the 4-inch River Sweeper pump in the morning. Once the pump was started, both the River Sweeper and hand-held retriever were used. With both of these units operating simultaneously, pickup rates of up to 200 gpm were achieved. After cleaning 20 feet, the sedimentation tank was full and pickup operations were suspended and treatment started.

In the afternoon, after treatment was completed, pickup operations resumed and another 20 linear feet were cleaned and the treatment system operated. Progress was impaired by clogging of the suction lines on both pickup devices. The lines were cleaned out by reversing the suction and discharge hoses on the pump and using river water as a source of backflush water. Although this method worked, it was very time-consuming. As a result, valves for both pumps were purchased and installed that evening. These valves allowed for backflush to be accomplished much quicker and easier. During the day it was also found that the muds picked up were mostly of a silty nature and contained little sand or gravel. Thus, the apex discharge from the hydrocyclone was very dilute and contained little particulate matter, and the apex

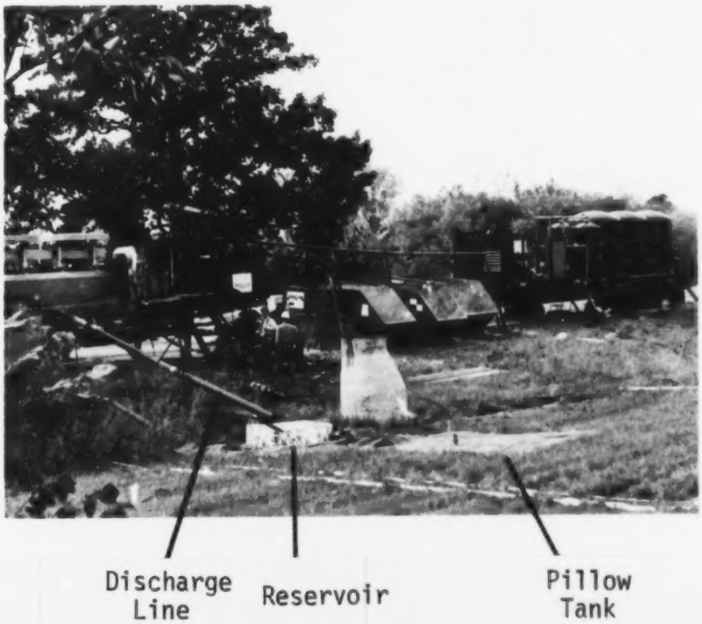

Figure 20. Creosote discharge line, reservoir and tank.

discharge was closed and all flow diverted either to hydrocyclone recycle or to the sedimentation tank.

On Thursday, October 5, operations began running on a smoother, more continuous schedule. The system was run on a two-segment basis, with 25 linear feet cleaned in the morning and 25 in the afternoon. The treatment process was run twice, once following the morning pickup operations and then following the afternoon pickup operation. Because of the improvement of the River Sweeper operator's ability in handling this device, the ratio of water picked up to mud picked up greatly decreased. For the entire 50 feet cleaned during the day, only 16,800 gallons were pumped to treatment from both pickup devices. This compared to 15,000 gallons being pumped the first day by the River Sweeper alone, in cleaning only 20 feet. On Friday, October 6, the morning was spent pumping sludge out of the sedimentation tank to liquid haulers. A total of 5000 gallons of sludge was removed from the sedimentation tank. Following the removal of the sludge, the mixed media filters were backwashed for 10 minutes, using 2000 gallons of previously treated water that had been stored in the pillow tanks. Pickup operations resumed in the afternoon with 30 linear feet being cleaned. Operations were suspended for the day after the mast housing the suction line was torn off of its supporting structure when the suction hose leading to the pump became entangled in the framework of the River Sweeper while the operator was moving the mast.

Coagulant addition was completed in the evening. However, since it was known that pickup operations would be delayed the following morning, until the mast was repaired, the treatment system was not run until then. It was felt that the additional overnight settling time would be advantageous.

Pickup operations on Saturday, October 7, began upon completion of repairs to the mast and the termination of the treatment process. Saturday was broken up into two segments, as had become the pattern. A total of 60 feet were cleaned, 30 feet during each segment. Following the morning treatment operations, the sand filters were once again backwashed. Because no work was to be done on Sunday, treatment of the water in the sedimentation tank from the afternoon operations was terminated after coagulant addition. This allowed a settling time of 36 hours before treatment would again begin on Monday morning.

Operation resumed on Monday, October 9. This was the seventh of ten working days, and the sixth of eight cleanup days. The River Sweeper had now crossed under the railroad trestle. However, because of the irregularity of the shorelines, and the large amount of area inaccessible to the River Sweeper, the hand-held device was used a great deal in this area. The large amount of work that had to be done by the hand-held device caused its progress rate to fall behind that of the River Sweeper. A photograph shown in Figure 21, taken on Monday morning looking downstream, shows the hand-held device being utilized in the foreground, and the River Sweeper in the background, 100 feet downstream.

Two thousand gallons of sludge were pumped out of the sedimentation tank following completion of the treatment process, and then pickup operations resumed. Fifty linear feet were cleaned in the morning and 30 feet in the afternoon. Settling was allowed to occur overnight once again.

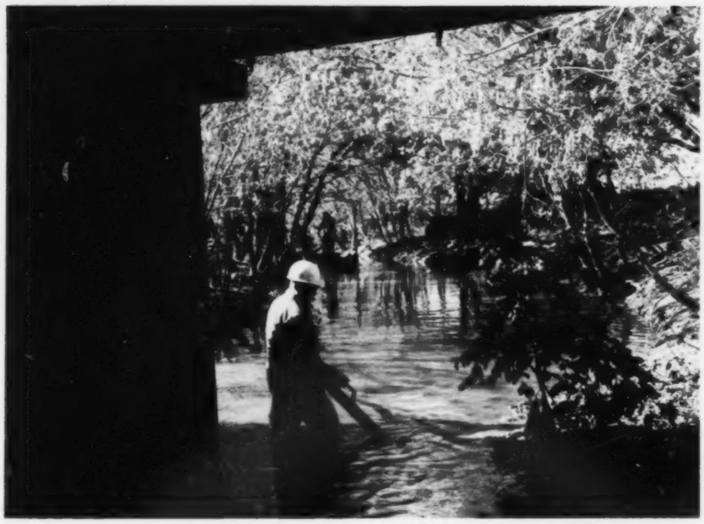

Figure 21. Hand-held retriever and river sweeper.

By Tuesday, October 10, system operation was becoming routine, following the two-segment-per-day schedule. During the morning, 45 feet were cleaned, with an additional 65 feet cleaned in the afternoon. Wednesday was the ninth working day and the eighth, or last, day of River Sweeper operation. Sixty feet were cleaned in the morning, followed by treatment and the removal of 2100 gallons of sludge. The last 50 feet of the 500-foot demonstration stretch were cleaned in the afternoon, thus terminating River Sweeper operations for the project. The coagulated water in the sedimentation tank from the afternoon's noon's operation was allowed to settle overnight. Since the last 50 feet of the river contained much plant life known as Heteranthera dubia (pickerel weeds) which not only clogged the River Sweeper suction line but also contained much creosote adhering to its surface, it was raked up by workers in the river. Figure 22 shows the material being gathered into a boat preceding the River Sweeper.

On Thursday, October 12, the tenth and last working day, 2 hours were spent using the hand-held device to clean the shoreline near Bradley Road. Following this, the treatment system was operated and then 4600 gallons of sludge were removed, leaving the sedimentation tank empty. the remainder of the day was spent in disassembling and packing the system for transport back to Rex. The following morning the treatment vehicles and a flatbed truck containing the remaining equipment were picked up by the cartage company. On Friday afternoon, October 13, the project site for demonstration of the river cleanup system was once again vacant parkland. Over 125,000 gallons of muds had been removed from the bottom of the river and processed, with 17,200 gallons removed as sludge and the remainder returned to the river in a quality better than that of the river water itself.

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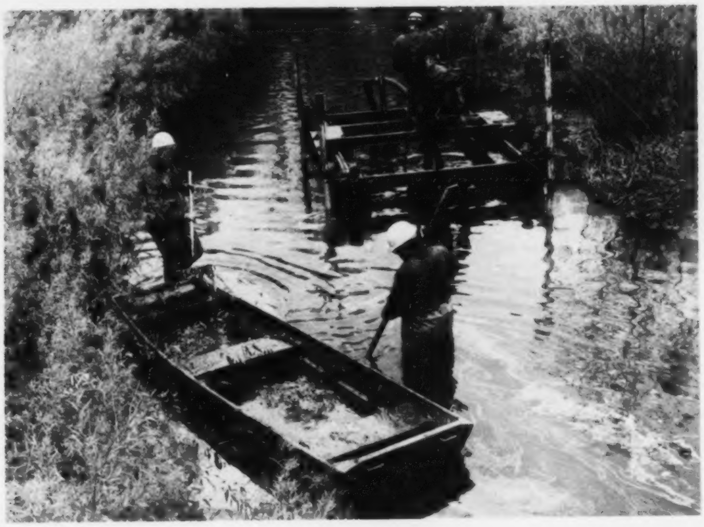

Figure 22. Manual removal of weeds.

Manpower Requirements

Operation of the demonstration project required the services of seven full-time people at the project site, five associated with the pickup operation and two with the operation of the treatment process. At the river itself, one man operated the River Sweeper and one man operated the hand-held device. Two men were stationed at the pumps, one for the River Sweeper pump and one for the hand-held retriever pump. The main function of these men was to keep the pumps running in coordination with the retrieval devices, to change the necessary valve settings for backflush purposes, and to assist in the moving of the River Sweeper to new locations. One man was also present with a walkie-talkie to coordinate pumping operations with the operator of the froth flotation unit at the treatment site. One of the most time-consuming and burdensome tasks for the retrieval crew was the removal of debris from the river. This primarily consisted of logs and dead tree limbs. In addition, many of the trees had dead branches hanging over the river which had to be removed to make the river passable.

At the treatment system one man operated the froth flotation unit while the second man prepared the Hazardous Spills Vehicle for operation, determined and prepared coagulant dosages, and transferred the top skimmings from the wading pool to the pillow tank. When the Hazardous Spills Vehicle was run in the evening, these two men were required to remain at the site for this operation.

REX CHAINBELT RESULTS AND DISCUSSIONS

SAMPLING POINTS, PROCEDURES, AND ANALYTICAL METHODS

Samples were taken during the entire time of operation of the pickup and treatment processes. Sample locations and analyses performed were chosen with the intent of characterizing the raw flow to the treatment process, the fate of contaminants during the various treatment steps, and the quality of the water ultimately returned to the Little Menomonee River. In addition, samples were taken of river water upstream and downstream of the demonstration stretch to determine the effect of operations on the river water. The sample locations and analyses performed are listed below.

Raw Flow to Treatment

- Total Solids
- Suspended Solids
- Hexane Extractables
- Settled Volume

Effluent from Froth Flotation

- Total Solids
- Suspended Solids
- Hexane Extractables
- Settled Volume

Skimmings from Froth Flotation

- Total Solids
- Suspended Solids
- Hexane Extractables

Sedimentation Tank After Coagulation and Settling

- Total Solids
- Suspended Solids
- Hexane Extractables
- Total Organic Carbon
- Iron

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Effluent from Mixed Media Filtration

- Total Solids
- Suspended Solids
- Hexane Extractables
- Total Organic Carbon
- Iron

Effluent from Carbon Columns

- Total Solids
- Suspended Solids
- Hexane Extractables
- Total Organic Carbon
- Iron

Upstream and Downstream River Samples

- Total Solids
- Suspended Solids
- Total Organic Carbon
- Hexane Extractables
- Total Oxygen Demand

Analytical Methods

All applicable analyses were done according to Standard Methods. (Standard Methods for the Examination of Water and Wastewater, 13th ed., American Public Health Association, Washington, DC, 1971.) Since there is no specific analytical technique for defining creosote, a modification of the method for quantifying grease was suggested by the EPA. This method is a modification of 209A, Soxhlet Extraction Method, found in standard methods for grease determination (loc. cit.). The modification consisted of reducing the normal extraction cycle from 80 times down to 20 times. The initial samples from operation were run according to the modified 20-cycle procedure and according to the standard procedure. Results from the modified method were not reproducible and it was evident from the color of residue remaining in the thimble that a large amount of extractable material was still remaining. Comparison of results from both methods showed that up to 80% of the extractable material was still remaining after the modified cycle period. This matter was immediately brought to the attention of the EPA Project Officer. Upon mutual agreement, it was decided that the standard method of anlaysis using the longer extraction cycle time would be used. Therefore, all creosote measurements are reported as hexane extractables, determined by the standard procedure.

Total Organic Carbon (TOC) was analyzed in accordance with standard methods (Standard Methods for the Examination of Water and Wastewater, 13th ed., American Public Health Association, Washington, DC, 1971). The instrument used for this measurement was a Dow-Beckman Carbonaceous Analyzer Model 915, dual channel. The only analyses not performed by Rex Chainbelt laboratories were the Total Oxygen Demand (TOD) tests. These were performed by Aqua-Chem Inc. of Waukesha, Wisconsin. The instrument used was an Ionics Inc. Model 225 Total Oxygen Demand Analyzer. The only sample preparation needed for both TOC and

TOD analyses was rapid blending in a Waring blender that broke large particulates into smaller particles which would not clog the syringe used for sample injection. Iron concentrations were determined using atomic absorption spectrometry according to standard methods (loc. cit.). Samples for iron analysis were taken at various loations in the Hazardous Spills Vehicle treatment process. This was done because of the relatively high concentrations of $FeCl_3$ being used in the sedimentation tank. By tracing the iron it was possible to determine if coagulant additions were excessively high, and also to determine the effectiveness of the Hazardous Spills Vehicle in removing iron.

Samples of the raw flow to treatment were taken from the influent chamber to the first froth flotation cell. Samples of effluent from flotation were taken at both locations at 15-minute intervals during operation, and composited. One composite sample was produced each day. The sample of skimmings from froth flotation was composited throughout the day, prior to transferring the skimmings from the wading pool to the pillow tank. The samples of sedimentation tank effluent, mixed media filtration effluent, and carbon column effluent were taken manually at 5-minute intervals during operation of the Hazardous Spills Vehicle. One composite sample was taken from each location. Sampling ports were built into the piping of the Hazardous Spills Vehicle. On most days the Hazardous Spills Vehicle was used twice, as discussed earlier. Samples from the two separate operations were composited as one sample, representing the total results from that day. The upstream and downstream samples of river water were grab samples taken at the 500-foot mark upstream, and 50 feet downstream of the Bradley Road bridge. These were taken at the close of each working day. All samples were picked up the following morning and taken directly to the laboratories of Rex Chainbelt or Aqua-Chem for analyses.

RAW FLOW CHARACTERISTICS

The quality characteristics of the raw flow to the froth flotation vehicle are given in Table 1. Included are the gallons of flow to the unit, the concentrations of hexane extractables, total solids, and suspended solids, along with the settled volume of sludge after 1 hour. There was much variance in the concentration of hexane extractables. However, it can be seen that in general, high concentrations of suspended solids correlate with high creosote concentrations.

The total solids concentration in the raw flow varied between 1.08 and 5.31 percent by weight. The weighted mean concentration of total solids was 3.49%, less than that originally expected. The settled volume varied between 6% and 27% of the raw flow, with a weighted mean of 15.1%. The low concentrations of hexane extractables and solids on the first two days of operation can be attributed to the retrieval operator's inexperience with the pickup device as discussed earlier in this report. The low concentrations on the last day are a result of the fact that only the hand-held device was being used. This device was used to clean the river/shore interface and took in a very high ratio of water to bottom muds. Comparison of the hexane extractable concentrations on the remaining days with the concentrations in samples of bottom muds taken just before the project started (discussed later) shows some correlation. The higher concentrations found on day 4 appear to be due to the fact that the area being cleaned at this time had bottom muds with hexane extractable concentrations of up to 20% on a dry basis. On day 5 the concentration falls, as a

TABLE 1. RAW FLOW CHARACTERISTICS

Date	Day	Flow in Gallons	Hexane Extractables mg/l	Hexane Extractables lbs	Total Solids mg/l	Total Solids lbs	Suspended Solids mg/l	Suspended Solids lbs	Settled Volume, gal/1000 gal
10/3	Tue (2)	16,000	a	a	a	a	a	a	a
10/4	Wed (3)	24,000	585	117.1	17,904	3,583	17,800	3,562	70
10/5	Thu (4)	16,800	1,373	192.4	52,100	7,299	46,070	6,455	270
10/6	Fri (5)	12,000	453	45.3	19,450	1,947	17,434	1,745	90
10/7	Sat (6)	9,000	5,625	422.2	46,620	3,499	42,660	3,202	182
10/9	Mon (7)	14,650	4,003	489.1	51,290	6,267	51,066	6,239	210
10/10	Tue (8)	16,085	1,583	212.4	53,082	7,121	50,675	6,798	183
10/11	Wed (9)	10,693	1,141	101.8	18,029	1,608	17,100	1,525	60
10/12	Thu (10)	6,125	367	18.7	10,808	552	10,042	513	-
Total		125,353[b]		1599.0[c]		31,876[c]		30,039[c]	
Weighted Mean			1,753[d]		34,948[d]		32,936[d]		151[d]

a - No sample taken.

b - Actual flow is slightly higher with addition of top skimmings volume not included.

c - Plus some amount on 10/3.

d - Does not include 10/3.

result of crossing under the railroad trestle. In this area the river bottom was covered with large rocks, probably laid during trestle construction, with very little bottom mud being exposed. On day 6 the concentrations increase and then decrease daily through day 9. This follows the pattern of bottom muds also decreasing from a concentration of 0.82% in the area cleaned on day 6 to 0.28% in the area cleaned on day 9. However, it should be noted that a definite correlation is difficult, since variations in the operator's use of the suction line and the intermittent use of the hand-held device are two variables that may be more important than the bottom mud characteristics.

FROTH FLOTATION

Operation of the froth flotation unit proved to be very effective in the removal of a large amount of the hexane extractables present. Table 2 contains the effluent quality characteristics from this unit and also the pounds and percent of hexane extractables removed in this process. Over 1200 pounds of hexane extractables were removed in the froth flotation unit itself during the 8 days that complete samples were taken. This equals a removal of 76.5% of the total creosote that entered the unit. It should be noted there (as it is in Table 1) that the flow to treatment is actually slightly higher than reported because the volume of top skimmings is not included. Flow measurements were made of the effluent from the flotation unit but not of the raw flow to the unit or of the flow of top skimmings. Since the concentration of top skimmings was determined, it should have been possible to determine this flow and thus the raw flow by a mass balance. However, attempts at this yielded volumes of top skimmings in excess of the approximate amount known to be pumped from the pillow tank. This implies that the levels of hexane extractables in the top skimmings was probably greater than those reported. This can be attributed to the difficulty in gathering a representative sample of the skimmings. The problem probably stems from the fact that in the wading pool, from which the samples were taken, much of the material adhered to the sides of the tank or settled to the bottom and was not completely resuspended during sampling. The only reflection this has on the data, since effluent quality is known, is that the amount and thus the percentage creosote removed during the entire treatment process and the froth flotation process may be slightly higher than reported.

The four froth flotation cells comprising the flotation unit were manufactured by the Denver Equipment Company and each had a volume of 40 cubic feet for a total volume of 160 cubic feet. The total detection time of the raw flow in flotation varied between 12 minutes at a flow of 100 gpm down to 6 minutes at 200 gpm. The best froth (thickest) was found to be produced with the air supply wide open. This air flowrate is 550 cfm with a static pressure of 17.6 ounces per square inch with ratings selected to motor nameplate horsepower just equalling brake horsepower. The reported concentrations of top skimmings from the froth flotation unit are listed below. The concentrations are in mg/l of hexane extractables.

Date	Skimmings
10/3	--
10/4	575 mg/l
10/5	14,370 mg/l
10/6	21,910 mg/l

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TABLE 2. FROTH FLOTATION EFFLUENT

Date		Flow in Gallons	Hexane Extractables		Pounds Removed	Percent Removal	Total Solids		Suspended Solids	
			mg/l	lbs			mg/l	lbs	mg/l	lbs
10/3	Tue (2)	16,000	64	8.5	-	-	4,888	652	-	-
10/4	Wed (3)	24,000	335	67.1	50.0	42.7	16,866	3,375	15,300	3,062
10/5	Thu (4)	16,800	416	58.3	134.1	69.7	61,103	8,561	58,690	8,223
10/6	Fri (5)	12,000	190	19.0	26.3	58.1	18,622	1,863	16,633	1,664
10/7	Sat (6)	9,000	882	66.2	356.0	84.3	43,460	3,262	42,534	3,178
10/9	Mon (7)	14,650	712	87.0	402.1	82.2	53,250	6,506	52,760	6,446
10/10	Tue (8)	16,085	250	33.5	178.9	84.2	37,274	5,000	31,600	4,238
10/11	Wed (9)	10,693	354	31.6	70.2	68.9	18,417	1,642	17,685	1,577
10/12	Thu (10)	6,125	261	13.3	5.4	28.9	15,716	803	14,769	755
Total		125,353		384.5	1,223.0[a]			31,664		29,143[a]
Weighted Mean			368			76.5[b]	30,290[c]		31,973[b]	

a - Plus some amount on 10/3 not measured.

b - Does not include 10/3.

c - Note total solids mean less than suspended because of lack of suspended solids data on 10/3.

Date	Skimmings
10/7	23,180 mg/l
10/9	71,840 mg/l
10/10	8,130 mg/l
10/11	11,620 mg/l
10/12	2,094 mg/l

HYDROCYCLONE

Since it was found that the hydrocyclone was not needed for classification, the flowrate in the recycle loop was not critical. The only valve that had to be throttled was on the discharge line from the hydrocyclone to the sedimentation tank. This value was opened in proportion to the raw flow to the flotation unit, keeping the level in this unit constant. The only function of the hydrocyclone then was to supply the pumping capacity needed to transfer flow from the flotation unit to the sedimentation tank.

SEDIMENTATION TANK

The quality of the influent to the sedimentation tank is the same as that shown in Table 2 for flotation effluent. Performance of the sedimentation tank is summarized in Table 3. A total of 125,353 gallons were transferred to the sedimentation tank from the froth flotation unit for treatment. As shown in Table 3, coagulant dosages and settling times are specific for either the morning or afternoon segment. The longer settling times, 12 and 36 hours, represent overnight settling. These volumes were in fact treated the following morning, but reported as part of the previous day's data. Coagulant dosages were increased as time progressed because the buildup of sludge, occurring between removal, would cause a decrease in clear supernatant volume without the additional $FeCl_3$. The effect of the overnight or extended settling period is not reflected in the quality of the effluent from the tank, but rather in the quantity, because supernatant would only be pumped from the sedimentation tank until sludge began to appear. Thus, the efficiency of suspended solids removal was maintained at around 99%. The extended settling, however, did allow the sludge blanket on the bottom of the tank to compress and thus permit a much larger volume of supernatant to be removed when treatment began.

The sedimentation tank was effective in removing 94.9%, or 365.1 pounds of the hexane extractables in the flotation effluent. The effluent from the sedimentation tank, totalling 113,443 gallons, contained a mean concentration of 20.5 mg/l of hexane extractables. This means that after froth flotation and sedimentation, a total of 98.8% of the hexane extractables had been removed. In addition, 98.9% of the suspended solids, or 28,841 pounds of material, were removed during sedimentation. The effluent had a mean concentration of 331 mg/l of suspended solids. The sludge was pumped out of the sedimentation tank to a commercial liquid hauler when the volume of sludge built up enough to hinder supernatant quality. Listed below is a schedule of sludge removal dates and corresponding volume.

TABLE 3. SEDIMENTATION TANK PERFORMANCE

					Settling	Hexane Extractables				Suspended Solids			
Date	Day		Gallons	$FeCl_3$ mg/l	Time (hrs)	In mg/l	Out mg/l	lbs Removed	% Rem.	In mg/l	Out mg/l	lbs Rem.	% Rem.
10/3	Tues (2)	pm	16,000	40	1.0	64	56	1.5	18.8	-	110	-	-
10/4	Wed (3)	am	13,000	40	0.33	335	33	61.1	90.9	15,300	104	3,043	99.3
		pm	11,000	50	1.0								
10/5	Thu (4)	am	9,300	70	1.0	416	20	56.2	96.3	58,690	630	8,156	98.9
		pm	7,500	77	0.75								
10/6	Fri (5)	pm	12,000	51	12	190	4	18.7	98.5	16,633	78	1,658	99.5
10/7	Sat (6)	am	4,500	150	0.5	882	11	65.0	98.3	42,534	220	3,155	99.5
		pm	4,500	150	36								
10/9	Mon (7)	am	10,500	115	0.5	712	4	86.6	95.4	52,760	160	6,430	99.7
		pm	4,150	120	12								
10/10	Tue (8)	am	9,900	130	0.5	250	3	33.2	99.1	31,600	184	4,218	99.4
		pm	6,185	130	0.5								
10/11	Wed (9)	am	4,993	140	0.5	354	19	29.9	94.7	17,685	1,590	1,437	91.0
		pm	5,700	200	12								
10/12	Thu (10)	am	6,125	150	0.5	261	7	12.9	96.9	14,769	142	744	99.1
Total			125,353[a]					365.1				28,841[c]	
Weighted Mean						368	20.5		94.9	31,973[d]	331		98.9[d]

a - 17,200 gallons of this total were removed as sludge with the balance going on to treatment in the Hazardous Spills Vehicle.

b - Calculated by multiplying concentration in times flow in minus concentration out times flow out. The flow out equals flow in minus that removed as sludge.

c - Plus amount on 10/3 not measured.

d - Not including 10/3.

Date	Gallons Removed
10/3	0
10/4	0
10/5	5000
10/6	0
10/7	2000
10/9	0
10/10	3500
10/11	2100
10/12	4600

In addition, approximately 2000 gallons of top skimmings were pumped from the pillow tank to disposal. A total of 17,200 gallons of sludge were removed from the bottom of the sedimentation tank. Calculation yields an average solids concentration of 201,000 mg/l in the sludge.

Hazardous Spills Vehicles

Operation of the Hazardous Spills Vehicle followed completion of settling in the sedimentation tank. The quality of the influent to the vehicle is shown in Table 3 for sedimentation tank effluent. Flowrates to mixed media filtration and then to carbon adsorption were varied between 125 and 200 gpm (the unit has a maximum hydraulic capacity of 200 gpm) with a 150-gpm rate maintained the majority of the time. This rate yields a loading rate of 5.21 gallons per minute per square foot on the mixed media filters and 3.9 gallons per minute per square foot on the one carbon column used with a carbon contact time of 11.6 minutes. During the 9 days of operation the carbon columns never required backwashing. The mixed media filters were backwashed twice, the first time during the evening of October 5, and the second time during the morning of October 7. Both times the backwash rate was 150 gpm for a period of 4 to 5 minutes on each filter.

Performance of the mixed media filters and carbon column is summarized in Table 4. The prime objective of the mixed media filters is prevention of blinding of the carbon by the particulate material. In so doing, the filters were also effective in removing a large portion of the hexane extractables and the iron which was added as a flocculant. Although TOC removals approached 65%, with an average concentration of less than 15 mg/l in the effluent, this was less than originally anticipated. However, removal of suspended solids and hexane extractables in the Hazardous Spills Vehicle averaged 89.9 and 99.2, respectively. A grab sample of raw flow and final effluent is shown in Figure 23. Thus, the performance of the Hazardous Spills Vehicle was considered most satisfactory, with notably high removal efficiencies of hexane extractables by the filters and also of suspended solids by both steps. The high removals of hexane extractables in the mixed media filters can be attributed to the fact that almost all of the hexane extractables which were not adsorbed on particulate were removed in the froth flotation. The mean concentration of hexane extractables in the effluent returning to the river was 2.3 mg/l and that of the suspended solids was less than 2.4 mg/l; both of these are lower than the same parameters of the river water itself.

TABLE 4. PERFORMANCE OF MOBILE HAZARDOUS SPILLS TREATMENT VEHICLE

					Hexane Extractables				Total Organic Carbon			
Date	Day		Gallons	Flow Rate gpm	Sed. Tank Effl. mg/1	Mixed Media Effl. mg/1	Carbon Col. Effl. mg/1	% Rem.	Sed. Tank Effl. mg/1	Mixed Media Effl. mg/1	Carbon Col. Effl. mg/1	% Rem.
10/3	Tue (2)	pm	15,000	200	56	12	3	94.6	40	38	4	90.0
10/4	Wed (3)	am pm	12,000 10,000	150 150	33	14	2	93.9	35	34	13	62.9
10/5	Thu (4)	am pm	6,432 6,353	150 150	20	11	1	95.0	65	35	17	73.8
10/6	Fri (5)	pm	8,669	150	4	4	1	75.0	42	35	20	52.4
10/7	Sat (6)	am pm	4,272 8,317	150 150	11	8	5	54.5	44	36	23	47.7
10/9	Mon (7)	am pm	6,362 5,754	150 150	4	3	1	75.0	32	45	20	37.5
10/10	Tue (8)	am pm	6,002 6,726	150 150	3	2	1	66.7	28	33	15	46.4
10/11	Wed (9)	am pm	3,844 6,734	125 150	19	5	4	78.9	81	29	13	84.0
10/12	Thu (10)	am	6,978	150	7	5	2	71.4	15	19	14	6.7
Total			113,443									
Weighted Mean					20.5	8.1	2.3	89.0	42.5	34.6	14.9	64.8

(continued)

TABLE 4 (continued)

					Total Solids				Suspended Solids			
Date	Day		Gallons	Flow Rate gpm	Sed. Tank Effl. mg/l	Mixed Media Effl. mg/l	Carbon Col. Effl. mg/l	% Rem.	Sed. Tank Effl. mg/l	Mixed Media Effl. mg/l	Carbon Col. Effl. mg/l	% Rem.
10/3	Tue (2)	pm	15,000	200	889	858	490	44.8	110	58	2	98.1
10/4	Wed (3)	am pm	12,000 10,000	150 150	998	977	792	20.6	104	112	<1	>99.0
10/5	Thu (4)	am pm	6,432 6,353	150 150	1753	1121	908	48.2	630	115	1	99.8
10/6	Fri (5)	am	8,669	150	1140	1080	1013	11.1	78	26	<1	>98.7
10/7	Sat (6)	am pm	4,272 8,317	150 150	1293	1077	1027	20.5	220	36	<1	>99.5
10/9	Mon (7)	am pm	6,362 5,754	150 150	1299	1401	1145	11.8	160	199	4	97.5
10/10	Tue (8)	am pm	6,002 6,726	150 150	1376	1376	1204	12.5	184	199	7	96.1
10/11	Wed (9)	am pm	3,855 6,734	125 150	2744	1520	1215	55.7	1590	297	1	99.9
10/12	Thu (10)	am	6,978	150	1294	1199	1322	-	142	57	5	96.4
Total			113,443									
Weighted Mean					1368	1151	964	29.4	331	123	<2.4	>99.2

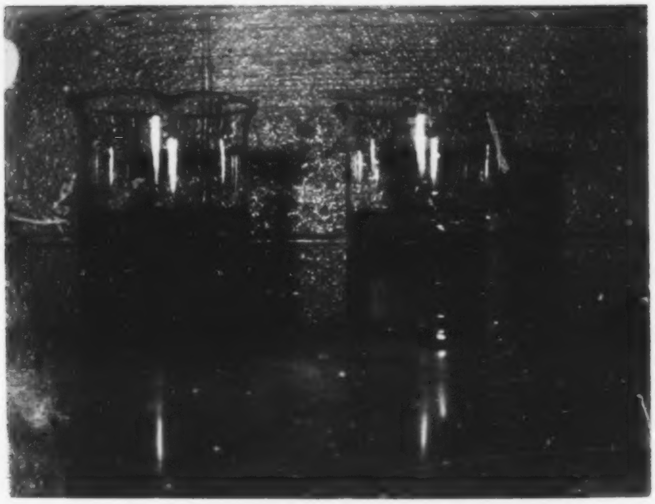

Figure 23. Raw flow and final effluent.

Summary of Process Effectiveness

A summary of the net process effectiveness is shown in Table 5. A total of 113,433 gallons were treated and discharged by the sedimentation tank and Hazardous Spills Vehicle. The figure includes 4000 gallons of water that had been previously treated, stored, and used for the two backwashing operations, making the actual total 4000 less, or 109,443 gallons. Adding to this the 17,200 gallons removed as sludge increases the total to 126,643 gallons. This agrees within approximately 15% with the measured raw flow of 125,353 gallons. The entire process removed a total of 1597 pounds of hexane extractables, or 99.8% of that removed from the river. Over 30,000 pounds of suspended solids, or greater than 99.9% of those extracted from the river, were also removed. The hexane extractables were reduced from 1753 mg/l in the raw flow to 2.3 mg/l in the effluent, with the suspended solids decreasing from 32,936 mg/l in the raw flow to less than 2.4 mg/l in the effluent. A bar graph showing the pounds and percentage of the hexane extractables removed in each unit operation is shown in Figure 24.

One of the objectives in the project was that the effluent from treatment would be returned to the river with concentrations of suspended solids and hexane extractables less than that of the river water itself. It was also important that the pickup and treatment operations did not cause a degrading of the quality of the river. Table 6 shows the daily quality of the river water upstream and downstream, and the quality of effluent discharge from the treatment process. As mentioned before, on all days the effluent quality was of equal or better quality than that of either the upstream or downstream river water. Comparison of the upstream and downstream river water quality there revealed no apparent effect of operations on river water quality. There were daily variations as to whether the upstream or downstream river water was of better

TABLE 5. NET REX CHAINBELT TREATMENT PROCESS EFFECTIVENESS

				Hexane Extractables					
		Volume, Gallons		Influent		Effluent		lbs	%
Date	Day	Influent	Effluent	mg/l	lbs	mg/l	lbs	Rem.	Rem.
10/3	Tue (2)	16,000	15,000	-	-	3	0.38	-	-
10/4	Wed (3)	24,000	22,000	585	117.1	2	0.37	116.7	99.6
10/5	Thu (4)	16,800	12,785	1373	192.4	1	0.11	192.3	99.9
10/6	Fri (5)	12,000	866^a	453	45.3	1	0.08	45.2	99.7
10/7	Sat (6)	9,000	12,589	5625	422.2	5	0.54	421.7	99.8
10/9	Mon (7)	14,650	12,116	4003	489.1	1	0.10	489.0	99.9
10/10	Tue (8)	16,085	12,728	1583	212.4	1	0.11	212.3	99.9
10/11	Wed (9)	10,693	10,578	1141	101.8	4	0.37	101.4	99.6
10/12	Thu (10)	6,025	6,978	367	18.7	2	0.12	18.6	99.4
Total		125,353	$113,443^c$		1599.0^b		2.18	1596.8	
Weighted Mean				1753^a		2.3			99.8^a

a - Does not include 10/3.

b - Plus amount on 10/3 not measured.

c - 17,200 gallons removed as sludge.

(continued)

TABLE 5 (continued)

		Volume, Gallons		Suspended Solids					
				Influent		Effluent			
Date	Day	Influent	Effluent	mg/1	lbs	mg/1	lbs	Rem.	Rem.
10/3	Tue (2)	16,000	15,000	-	-	2	0.25	-	-
10/4	Wed (3)	24,000	22,000	17,800	3,562	<1	<0.18	>3,562	>99.9
10/5	Thu (4)	16,800	12,785	46,070	6,455	1	0.11	6,455	99.9
10/6	Fri (5)	12,000	866[a]	17,434	1,745	<1	<0.08	>1,745	>99.9
10/7	Sat (6)	9,000	12,589	42,660	3,202	<1	<0.11	>3,202	>99.9
10/9	Mon (7)	14,650	12,116	51,066	6,239	4	0.40	6,239	99.9
10/10	Tue (8)	16,085	12,728	50,675	6,798	7	0.76	6,797	99.9
10/11	Wed (9)	10,693	10,578	17,100	1,525	1	0.09	1,525	99.9
10/12	Thu (10)	6,125	6,978	10,042	513	5	0.29	513	99.9
Total		125,353	113,443[c]		30,039[b]		<2.27	>30,037	
Weighted Mean				32,936[a]		<2.4			>99.9

a - Does not include 10/3.

b - Plus amount on 10/3 not measured.

c - 17,200 gallons removed as sludge.

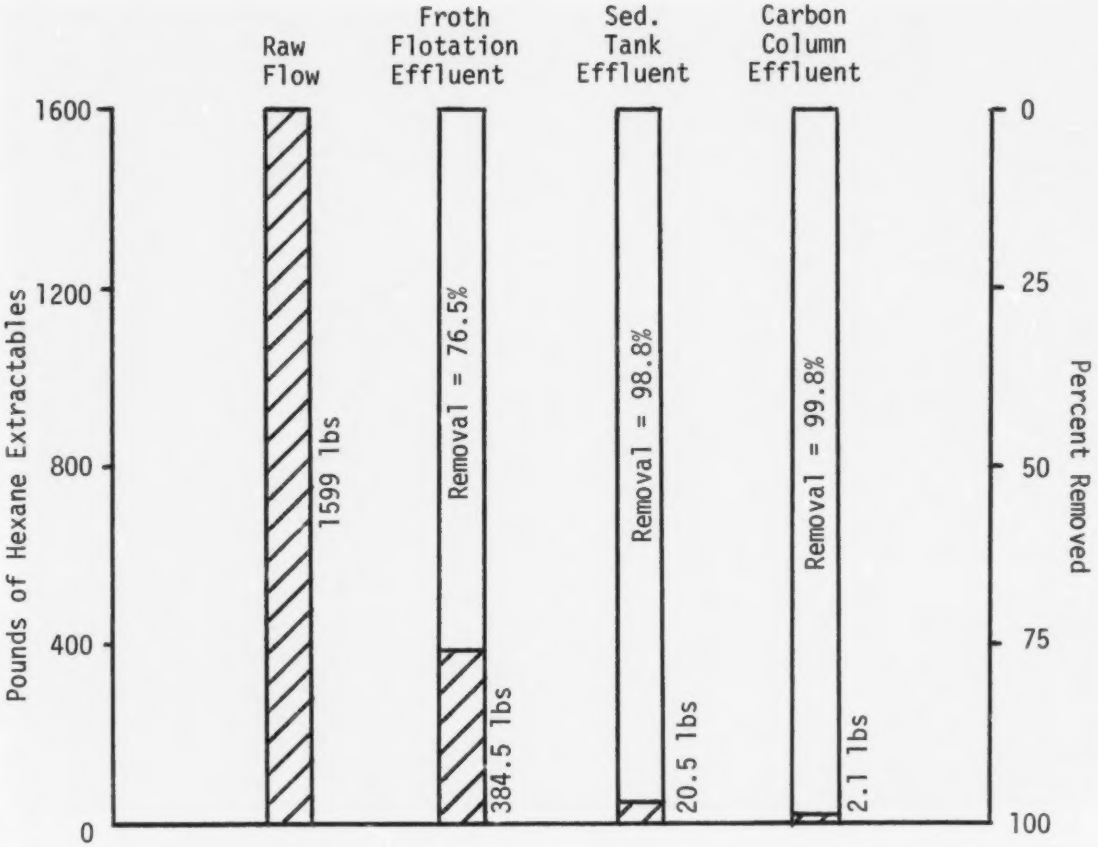

Figure 24. Bar graph of hexane extractable removals.

quality, thus negating any pattern that would be a result of the demonstration project operations.

CHARACTERIZATION OF RIVER WATER AND BOTTOM MUDS

Sampling Methodology and Equipment

In order to completely characterize the condition of the bottom muds and river water, a complete sampling program was conducted both before and after the project demonstration. Sample locations were at 100-foot intervals within the test stretch, at 400 feet upstream from the northern end of the test stretch and at 200 feet downstream of Bradley Road. The samples were collected by personnel wading the river. Sampling began downstream and proceeded upstream in an attempt to eliminate the effect of the welling up of the bottom deposits and subsequent redeposition of material in future sampling locations. Sampling began 2 feet east of the west bank and proceeded east at 5-foot intervals. At

TABLE 6. UPSTREAM AND DOWNSTREAM RIVER WATER QUALITY - REX CHAINBELT SYSTEM

Date	Hexane Extractables			Suspended Solids			Total Organic Carbons		
	Upstream mg/l	Downstream mg/l	Effluent mg/l	Upstream mg/l	Downstream mg/l	Effluent mg/l	Upstream mg/l	Downstream mg/l	Effluent mg/l
10/3	-	-	3	-	-	2	-	-	4
10/4	13	10	2	22	24	<1	42	42	13
10/5	11	1	1	18	25	1	42	42	17
10/6	-	-	1	-	-	<1	-	-	20
10/7	3	7	5	11	37	<1	45	47	23
10/9	2	<1	1	108	35	4	47	42	20
10/10	4	11	1	30	84	7	38	37	15
10/11	8	12	4	43	94	1	32	32	13
10/12	-	-	2	-	-	5	-	-	-

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each of the sampling points the following sequence of events took place:

1. River width and depth were measured and recorded.
2. Dissolved oxygen, temperature, and conductivity were measured, beginning 3 inches from the bottom and proceeding upward at 1-foot intervals to the surface.
3. Water samples were drawn beginning 3 inches from the bottom and proceeding upward at 1-foot intervals to the surface.
4. A benthic sample was collected using a dredge and a 30-mesh wash bucket.
5. A 12-inch bottom core was taken and the visible profile of this core recorded.

The equipment used in the sampling consisted of a Phleger coring device, an Eckmann dredge which proved suitable for the clay bottom, a Kemmerer acrylic plastic water sampler, and a wading hook for plant collections. A field log was maintained for the data collected on site. A sample of the format used in this log is shown in Figure 25. The river water samples were later analyzed for pH, turbidity, suspended solids, TOC, ammonia nitrogen, nitrate nitrogen, total phosphate, and TOD. The bottom mud samples were analyzed for hexane extractable concentrations. The before samples were taken on September 25 and 26, and the after samples on October 17 and 18.

Bottom Mud Characterization and Change

In general, the bottom mud of the Little Menomonee can be classified as clay with mixture of sand and gravel appearing at the railroad trestle and at Bradley Road. Large rocks, some larger than 4 inches in diameter, were found near the trestle and scattered within 150 feet upstream of Bradley Road. At the trestle location, gravel and debris were observed throughout the entire 12 inches of the core sample. In the samples taken during the before survey, the hexane extractables appeared to be concentrated in the upper 6 inches of the sample. However, at the 400- and 300-foot locations this material was found throughout the entire 12 inches of core sample. It is possible that these concentrations could exist much deeper than the top foot. Table 7 contains a visual description of the core samples taken at each cross-section before and after the cleanup operations.

Analytical determination of the hexane extractable concentration in each core sample was performed by first drying a portion of the sample before continuing the standard procedure. The hexane extractable concentration was then recorded as a percent of the dry solids based upon weight. Knowing the total solids concentration in the core sample (based upon weight) made it possible to report hexane extractable concentrations as pounds per hundred pounds of core sample. These values are reported in Table 8. The values of each sample in a cross-section were averaged, and these values were than averaged for the six cross-sections.

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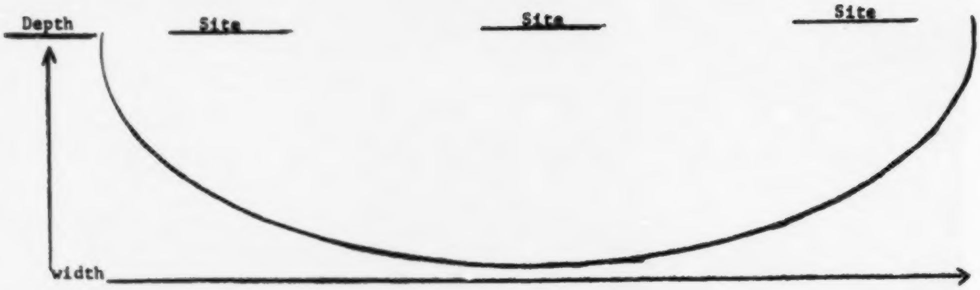
Collected by ____________

____

Location No. ____________


Depth
Site
Site
Site
Width

Bottom to Sample Depth/Inches	**Site**			**Site**			**Site**		
	DO	**Cond.**	**Temp.**	**DO**	**Cond.**	**Temp**	**DO**	**Cond.**	**Temp**
3									
15									
27									
39									
51									
63									

Bottom Type General:

Core Samples

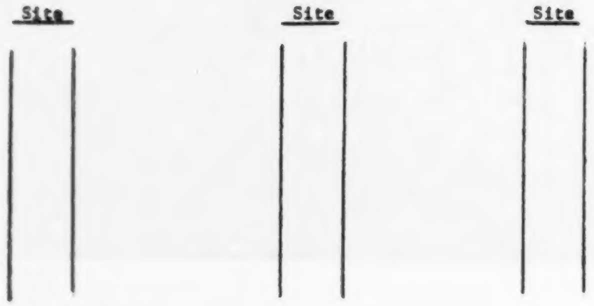

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Figure 25. Field Log - Rex Chainbelt

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TABLE 7. CORE SAMPLE DESCRIPTIONS (REX CHAINBELT)

Location	Before	After
400 feet upstream	3" of clay and creosote[a] 9" of clay	4" of clay and creosote 8" of clay
500 feet	3" of clay, gravel, organic debris 3" of clay and creosote 6" of clay	Thin creosote film 11.5" of clay
400 feet	12" of organic debris, gravel and creosote	3" of clay and creosote 9" of clay
300 feet	3" of clay and organic debris 9" of clay, creosote and organic debris	4" of clay, creosote, and organic debris 8" of clay and gravel
200 feet	4" of clay and creosote 8" of clay	3" of organic debris and creosote film 9" of clay
100 feet	4" of clay, creosote and organic debris 8" of clay, gravel and rock	1" of creosote and organic debris 11" of clay, gravel and rock
0 feet	12" of gravel and sand, trace of creosote on east bank	1" of clay and creosote 11" of gravel and sand
200 feet downstream	3" of sand and organic debris 4" of creosote and organic debris 5" of clay	2" of sand and creosote 4" of creosote and organic debris 6" of clay

[a] - Defined analytically as hexane extractables.

TABLE 8. BOTTOM MUD HEXANE EXTRACTABLE CONCENTRATIONS - REX CHAINBELT

	Before			After		
Sample Location (Ft from West Bank)	Total Solids %	Hexane Extractables %	Lbs of Hexane Extractables Per 100 lbs of Core Sample	Total Solids %	Hexane Extractables %	Lbs of Hexane Extractables Per 100 lbs of Core Sample
400 ft upstream						
2	38.8	3.52	1.37	47.9	1.39	0.67
7	40.2	1.70	0.68	46.3	1.00	0.46
12	40.6	1.22	0.50	53.8	0.73	0.39
Mean			0.85			0.51
500 ft						
2	43.2	3.92	1.69	50.1	2.68	1.34
7	48.2	0.96	0.47	46.1	1.00	0.46
12	66.6	0.52	0.35	57.4	0.29	0.17
Mean			0.84			0.66
400 ft						
2	48.3	11.8	5.70	47.1	4.77	2.25
7	50.2	20.0	10.04	54.2	0.96	0.52
12	65.7	0.50	0.33	55.5	0.35	0.19
Mean			5.36			0.99
300 ft						
2	59.1	0.75	0.44	50.1	1.55	0.78
7	52.1	0.79	0.41	57.2	2.04	1.17
12	58.8	0.82	0.48	49.6	1.27	0.63
17	59.5	0.42	0.25	57.6	1.37	0.72
22	62.3	0.45	0.18			
Mean			0.37			0.83

(continued)

TABLE 8 (continued)

			Before			After
Sample Location (Ft from West Bank)	Total Solids %	Hexane Extractables %	Lbs of Hexane Extractables Per 100 lbs of Core Sample	Total Solids %	Hexane Extractables %	Lbs of Hexane Extractables Per 100 lbs of Core Sample
200 ft						
2	60.3	0.31	0.19	58.5	0.57	0.33
7	64.0	0.35	0.22	64.0	0.22	0.14
12	62.6	0.32	0.20	57.4	0.22	0.13
Mean			0.20			0.20
100 ft						
2	68.3	0.15	0.10	63.8	0.17	0.11
7	78.7	0.60	0.47	56.4	0.89	0.50
12	65.4	0.33	0.22	70.2	0.32	0.22
Mean			0.26			0.27
0 ft						
2	84.3	0.28	0.24	72.9	0.30	0.22
7	83.8	0.013	0.01	69.5	0.077	0.05
12	56.4	0.66	0.37	87.5	0.10	0.08
17	80.9	0.47	0.38	74.9	0.10	0.07
Mean			0.25			0.10
200 ft downstream						
2	71.2	1.14	0.81	72.0	0.07	0.05
7	77.1	0.33	0.25	78.0	0.09	0.07
12	63.2	0.095	0.06	68.2	0.74	0.50
Mean			0.37			0.21

Inspection of Table 8 shows that the creosote concentrations decreased at both the upstream and downstream locations, which were not part of the cleanup operation. The upstream concentration decreased by 40%, and the downstream concentration by over 43%. These data point out severe problems in sampling methodology and/or technique. Changes in the hexane extractable concentrations of the untouched upstream and downstream sample locations indicate that two definite variables are affecting the sampling procedure, the continual suspension and deposition of materials in the test stretch, and the inability to sample at exactly the same location twice. Since the demonstration stretch is an unenclosed 500-foot stretch of the river, there is a continual deposit of materials from upstream into the demonstration stretch, and a continual scouring of materials from the stretch to downstream. It must be realized that since the river flow is constantly changing, the river/shore interface also changes. Samples were made relative to this shoreline, thus making it improbable that the exact same locations were sampled each time.

A sampling method that included perhaps 50 grab samples throughout each 100-foot interval, and composited these samples into one same per 100 feet would probably have given a better representation of the bottom mud quality. In addition, it is difficult to use a percent removal basis, or similar means, for determination of relative process efficiency. This is because the muds analyzed in the "after survey" were not of identical composition as those analyzed in the "before survey," since the better muds were removed during cleanup operations.

Change in the bottom mud characteristics can be seen in Table 7. The average depth of the clay, or compacted layer, increases by nearly 2 inches between the before and after surveys. At all eight cross-sections there was a change in either the depth or composition of the top layer of sediment.

Two cross-sections, the 400- and 300-foot locations, showed significant changes in hexane extractable concentrations. In both cases the probable explanation is evidenced by a definite change in the composition of the core samples. The samples taken at the 400-foot location in the "before" survey indicated a relatively uniform distribution of hexane extractables throughout the 12-inch core. The core consisted of mostly organic debris and gravel. The core samples from the "after" survey show a tremendous decrease in hexane extractable content, with the sample consisting primarily of compacted clay. This indicates the top sediment had been removed during cleanup operations and the compacted layer had been reached. Traces of hexane extractables in this sample strongly indicate that the contaminants lie more than a foot below the mud surface. Core samples taken at the 300-foot location in the "before" survey indicated a relatively uniform distribution of hexane extractables. The core samples from the "after" survey are not only similar in composition, but have a higher concentration of hexane extractables. This indeed suggests that the contaminated layer is much deeper than 12 inches.

The average hexane extractable concentration in the six cross-sections within the demonstration segment dropped from 1.21 lbs to 0.51 lbs per 100 lbs of core sample. This is a net decrease of 58%. However, with the preceding discussion of sampling variability, any further conjecture on the significance of this figure is unwarranted. Conclusions drawn from the results of the "before" and "after" bottom mud surveys included:

1. Hexane extractable material is present at depths of 12 inches and more in some locations.

2. Sediment transport within the river system does occur, and causes a high degree of variability in bottom mud hexane extractable concentrations.

3. The bottom muds sampled in the "after" survey had a hexane extractable concentration 58% lower than those in the "before" survey. However, sampling methodology does not permit valid comparisons based on a percent reduction basis.

River Water Characterization and Change

The samples of river water collected were analyzed and the individual results for each sample were averaged for each of the quality characteristics at the eight cross-sections. These mean values were used to represent the section. Table 9 contains the mean values from the "before" and "after" surveys for each section. Also included are the mean values from each of the characteristic columns for before and after, excluding the 400-foot upstream and 200-foot downstream samples. The change in pH and ammonia, nitrate, and total phosphate concentrations between the before and after survey is very small. The large drop in temperature from 15.6°C to 4.7°C, and the attendant large increase in dissolved oxygen concentration from 3.7 mg/l to 8.7 mg/l are notable.

Although it would be expected that the dissolved oxygen concentration would increase at a lower temperature, it is interesting that the percent of dissolved oxygen saturation increased from 37% to 65%. In addition, the total organic carbon and total oxygen demand concentrations decreased. However, because the demonstration stretch is not enclosed it is not valid to attribute any decrease in organic loading to the demonstration project. An increase in suspended solids concentration and conductivity were also seen. From the results of the "before" and "after" river water surveys, it can be concluded that there was little change in water quality, with the exception of the increased dissolved oxygen concentration, during the period surrounding and including the demonstration project.

Vegetation Profile

The vegetation profile of the river was restricted to within the natural water boundaries. It was observed, however, that the shoreline vegetation appeared to be in the pre-climax phase as characterized by ash and hawthorne. The restrictive tree canopies found within the 200- to 400-foot limits of the demonstration stretch affected the aquatic vegetation by limiting light penetration. The most commonly occurring water plants were found to be:

Anacharis canadensis (water weed)
Heteranthera dubia (mud plantain)
Limna minor (minor duckweed)

TABLE 9. RIVER WATER CHARACTERISTICS - REX CHAINBELT

Location		Temp. °C	Diss. Oxy. mg/1	TOD mg/1	Cond. µmhos cm	Turb. JTUs	Susp. Solids mg/1	TOC mg/1	NH_3 -N mg/1	NO_3 -N mg/1	Total Phos. P mg/1	pH
400 ft Upstream	Before	15.5	4.4	56	690	59	91	27	0.31	1.75	0.36	7.4
	After	4.5	8.6	51	1150	25	46	25	0.32	2.80	0.13	8.1
500 ft	Before	15.5	4.1	61	675	62	76	30	0.35	1.77	0.25	7.4
	After	4.5	8.3	60	1000	75	135	27	0.40	2.69	0.18	8.1
400 ft	Before	15.5	4.1	60	686	55	78	31	0.28	1.82	0.24	7.4
	After	4.5	8.6	58	1100	39	142	26	0.42	2.77	0.19	8.1
300 ft	Before	15.7	4.7	60	675	54	80	31	0.31	1.79	0.24	7.4
	After	4.5	8.5	50	1133	21	38	27	0.40	2.73	0.27	8.0
200 ft	Before	16.0	3.2	76	900	19	28	54	0.48	2.32	0.17	7.5
	After	5.0	8.4	54	1166	43	159	32	0.36	2.82	0.19	8.0
100 ft	Before	15.8	3.1	74	895	21	39	50	0.46	2.34	0.19	7.4
	After	5.0	8.6	53	1137	61	261	40	0.43	2.95	0.31	8.0
0 ft Bradley Rd	Before	15.0	3.3	82	955	36	108	50	0.43	2.39	0.23	7.4
	After	4.8	8.8	48	1116	29	103	26	0.43	2.90	0.33	8.0
200 ft Downstream	Before	15.5	3.3	71	975	28	123	47	0.45	2.25	0.18	7.4
	After	4.5	9.0	53	1100	72	289	33	0.39	2.86	0.26	7.9
Mean*	Before	15.6	3.7	68.8	798	41.2	68.2	41	0.38	2.07	0.22	7.4
	After	4.7	8.6	53.8	1109	44.7	139.7	29.7	0.41	2.81	0.25	8.0

* Mean values do not include 400 feet upstream or 200 feet downstream.

Potamogeton foliosus (leafy pond weed)
Saggittaria latifolia (duck potato)
Typha latiofolia (broadleaf cattail)

In general, the upper 300 feet of the test stretch were sparsely populated, with the 400-foot mark having the least aquatic vegetation. Beginning at the 200-foot mark and moving downstream toward Bradley Road, vast mats of waterweed and plantain were observed. Collections within this section indicated that hexane extractable materials were being trapped in the leafy portions of the plants. Based upon the bottom mud data and this observation, it can be concluded that the vegetation functions as a strainer, removing hexane extractable materials from the water during periods of low velocity. Gentle stirring of the vegetation with the collection hook caused the visible release of some hexane extractable material into the waterway. This indicates that during periods of high velocity and turbulence there is a release of some of this material which eventually settles to the bottom. Although a great deal of the aquatic vegetation was removed during the cleanup procedure, a sufficient population was found during the "after" survey to assure the complete vegetative repopulation of the river within this test reach.

Algae and Benthic Survey

A portion of each water sample taken within a river cross-section was set aside for a cross-sectional composite. This composite was used for visual free-floating algae identification and chlorophyll extraction. At least five slides were observed for each cross-section for a total of 40 slides. No free-floating algal forms were observed. The chlorophyll extractions made with 85% acetone using a technique designed for a Turner fluorometer indicated chlorophyll levels in the range of 10 to 25 parts per billion. Although it is believed there is a free-floating algal population, the density of it was not clearly detected. "After" survey samples indicated no apparent change. Attempts to collect fixed algal species such as Cladaphora also proved fruitless. All of the debris found in the water was coated with a layer of hexane extractable material which apparently served as a deterrent to algal attachment.

Benthic samples collected at each of the sampling points in the river indicated that no benthic population existed. Traces of a snail population were found under the railroad trestle. No other indications of benthic life were found in either the "before" or "after" samples.

SECTION 6

INDUSTRIAL BIO-TEST OPERATIONS

DEMONSTRATION SITE DESCRIPTION

The 500-foot segment of the river mandated as the location for the demonstration of the Industrial Bio-Test/R P Industries system extended 500 feet upstream from Calumet Road. This relatively straight section of the river, varying in width from 6 feet at its narrowest point to 12 feet at its widest point (for an estimated area of 4600 square feet), flows almost due south with a stream velocity very much dependent on the amount of rainfall-produced run-off from the adjacent and upstream farms and residential developments. A tributary drainage ditch that enters the stream at a point 300 feet downstream of the mandated starting point contributes little to the flow of the stream except in times of rainfall when it can become swollen with stormwater and join with the river to flood the adjacent lowland areas. THis recurring flooding made selection of the site for the operations base difficult, but dry ground was located on the east bank of the river just south of the tributary and the system was deployed there in a circus tent.

The narrowness of this segment of the stream, coupled with the presence of the aforementioned drainage ditch, made water level in the stream extremely sensitive to rainfall, rising and falling rapidly. For instance, measurements taken on October 16, 1972, gave a mean depth of the stream of 18.5 inches with a range of 10 to 29 inches. Measurements taken at the same locations on November 6, 1972, gave a mean depth of 24.2 inches with a range of 11 to 34 inches. In addition, on October 23, 1972, the river very nearly overflowed its banks, which are at least 48 inches above the stream bed.

The entire east bank of the river was covered by bushes and dense vegetation, making access difficult from this side. The west bank is less densely covered with grass. Some sections of the stream bed were covered with aquatic vegetation which was not present at the time the project was formulated. It was, therefore, agreed that the contractor could spend 2 days in site preparation removing the vegetation, in advance of the 10-day period assigned for bottom cleanup.

RETRIEVAL AND TREATMENT PROCESSES

The successful removal of the river bottom muds and associated contaminants, as well as production of a high-quality system effluent for return to the river, required the development of three distinct unit operations: a retrieval device to physically remove the mud and contaminant without plugging itself with them, a solids/liquid transport system capable of conveying the bottom muds from the retrieval device to the treatment process, and a process to reduce the volume of the mud slurry by dewatering and treating this water to remove any residual contaminants.

GENERAL PROCESS DESCRIPTION

Industrial Bio-Test utilized a relatively small-scale system, shown schematically in Figure 26. This lightweight, mobile, continuous-flow decontamination system was automated to the maximum extent possible and could be operated by only two men. Its main components were a hand-held vacuum nozzle, an in-line grass filter, a primary settling column, a Dynactor, a secondary settling column, a magnetic separator, and a final sand filter.

The creosote-mud slurry entered the system at a rate of 12 gpm through a nozzle that was designed in much the same manner as a vacuum cleaner nozzle, so that there were no constrictions where clogging could take place. The slurry then passed through a grass filter that was needed to protect the rest of the system from fouling caused by aquatic weeds and other debris from the river bottom.

From the filter, the slurry was pumped to the primary settling column where a flocculant was added and the mud and creosote were separated from the water. The settling column used for this purpose was a lightweight, inclined, parallel plate clarifier which is capable of processing approximately 15 gal of slurry per minute while occupying only 4 square feet of surface area

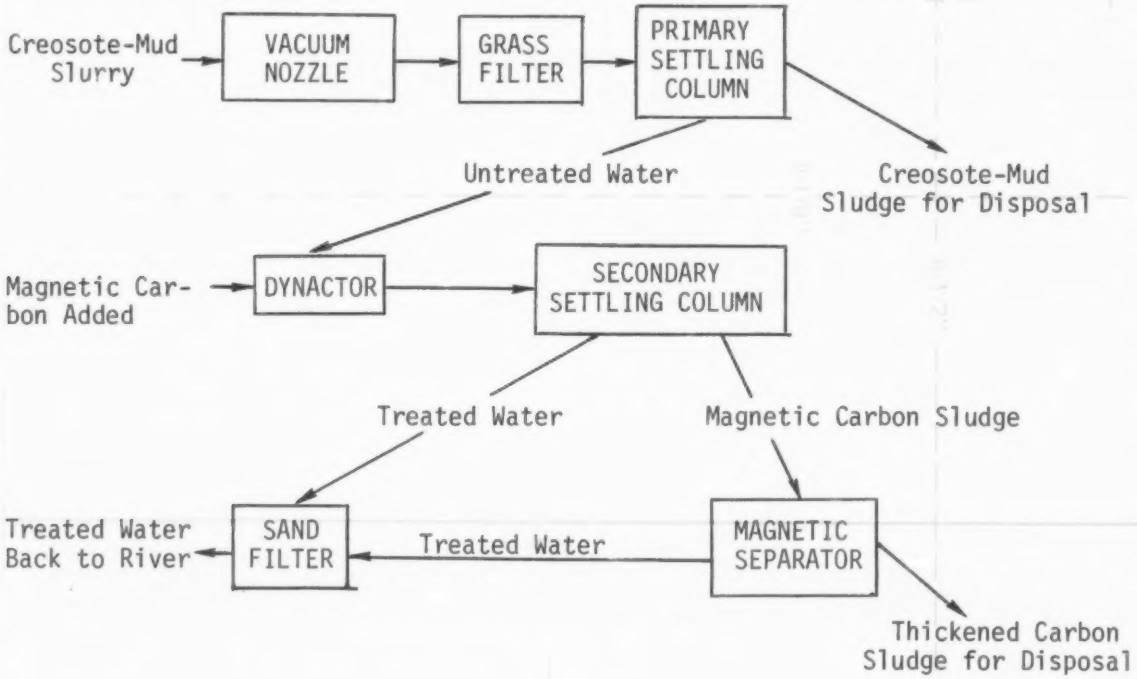
Creosote-Mud Slurry
VACUUM NOZZLE
GRASS FILTER
PRIMARY SETTLING COLUMN
Untreated Water
Creosote-Mud Sludge for Disposal
Magnetic Carbon Added
DYNACTOR
SECONDARY SETTLING COLUMN
Treated Water
Magnetic Carbon Sludge
Treated Water Back to River
SAND FILTER
Treated Water
MAGNETIC SEPARATOR
Thickened Carbon Sludge for Disposal

Figure 26. Schematic of Bio-Test treatment process.

(conventional separators of equal capacity require several times the space and are considerably heavier). The separated mud-creosote sludge was drained from the bottom of the settler and disposed of at the approved landfill.

The clarified liquid from the settling column was then pumped through the Dynactor, where a blend of 15% magnetic iron oxide and 85% powdered activated carbon was introduced to remove the residual dissolved or colloidal creosote from the water. The introduction of iron oxide with the carbon permits magnetic separation of both substances.

The effluent from the Dynactor was then introduced into the secondary settling column after a high molecular weight polymer had been added to floc the iron oxide carbon mixture. The thickened carbon sludge from the underflow of the settler was pumped to the continuous-flow magnetic separator for final dewatering.

The dewatered sludge was disposed of at the approved landfill. The clarified water from this process, along with the supernatant water from the secondary settler, were passed through a sand filter for final polishing. The effluent from the filter was then returned to the river.

Retrieval Device

Originally it was planned to produce a funnel-shaped device with a helical auger, driven by a small gear-reduced motor. The wide end of the funnel would be inserted into the mud. The rotating helix was intended to stir up the river bottom beneath the funnel, insuring pickup of contaminant and bottom mud to a depth determined by the projection of the auger. During design and river testing of the pickup funnel, it was found that the auger contributed nothing to the pickup of the fine silt bottom deposits and the auger concept was abandoned. After fabrication and testing of about 20 pickup funnel designs, a design very similar to the pickup attachment of a portable vacuum cleaner was selected. During operation, the narrow end of the nozzle, the internal surfaces of which are as smooth as possible to prevent plugging, is inserted into the mud to preclude the pickup of objects too big to enter the flexible rubber hose.

Solids/Liquid Transport

A pickup rate of 10 gallons per minute was chosen as the design rate of the transport system. It was thought that this would be sufficient to allow thorough cleaning of the assigned segment if a continuous flow at this rate could be maintained.

Primary Settling Column

Early in the program it was decided that specially designed continuous-flow, high-rate settling columns would be necessary to concentrate suspended solids from the pumped mud slurry into a thick sludge. Figure 27 is a general schematic diagram of the high-rate settling column constructed of PVC. The column is lightweight, corrosion-resistant, and rugged. The inclined plates are spaced 1 inch apart so that any solid particle needs to rise only 2 inches to be removed totally from the liquid stream. (Vertical rise equals

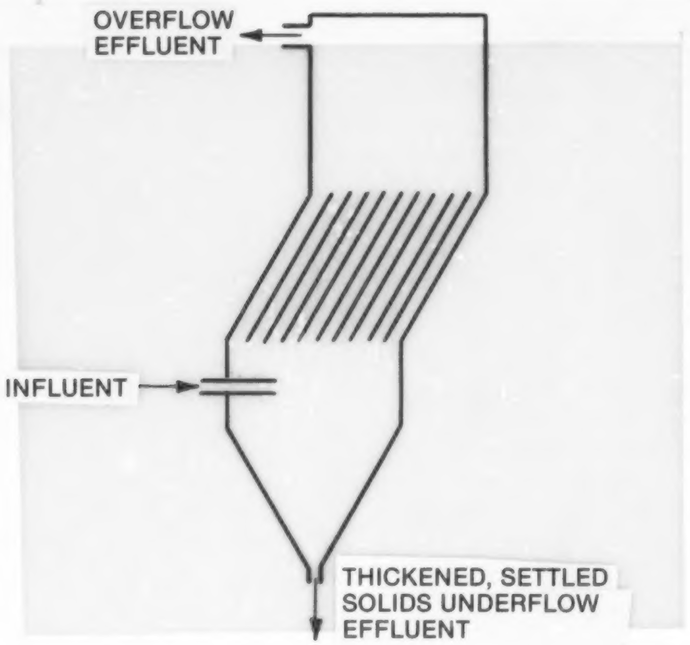

Figure 27. High-rate settling column.

spacing divided by sin 30°). The inclined section of the column is at an angle of 60° from the horizontal plane, an angle which is above the angle of repose for nearly all solids, thereby insuring that internal clogging will not occur.

By making use of advanced fluid dynamics technology and by employing lightweight plastics, a superior portable high-rate settling column was evolved. By comparison, similar settling vessels of earlier design are as much as five times heavier than the custom-built columns. In addition, the column could clarify 21,400 gallons per 24-hour day while occupying only 4 square feet of surface area, an improvement of 740% in surface area required over conventional settling basins and nearly twice as effective as earlier tube or plate types of high-rate settling systems. Moreover, the lightweight construction is itself an advantage, making possible the design of large systems having superior characteristics when compared with conventional settling vessels or "high rate" equipment available up to the present time.

Dynactor

Figure 28 shows a cross-sectional schematic diagram of the thin-film gas-liquid-particulate contact device used in Contract 68-01-0123 and modified for this program. The device, the Dynactor, was developed by R P Industries and weighs less than 40 lbs and is about 7 ft in height.

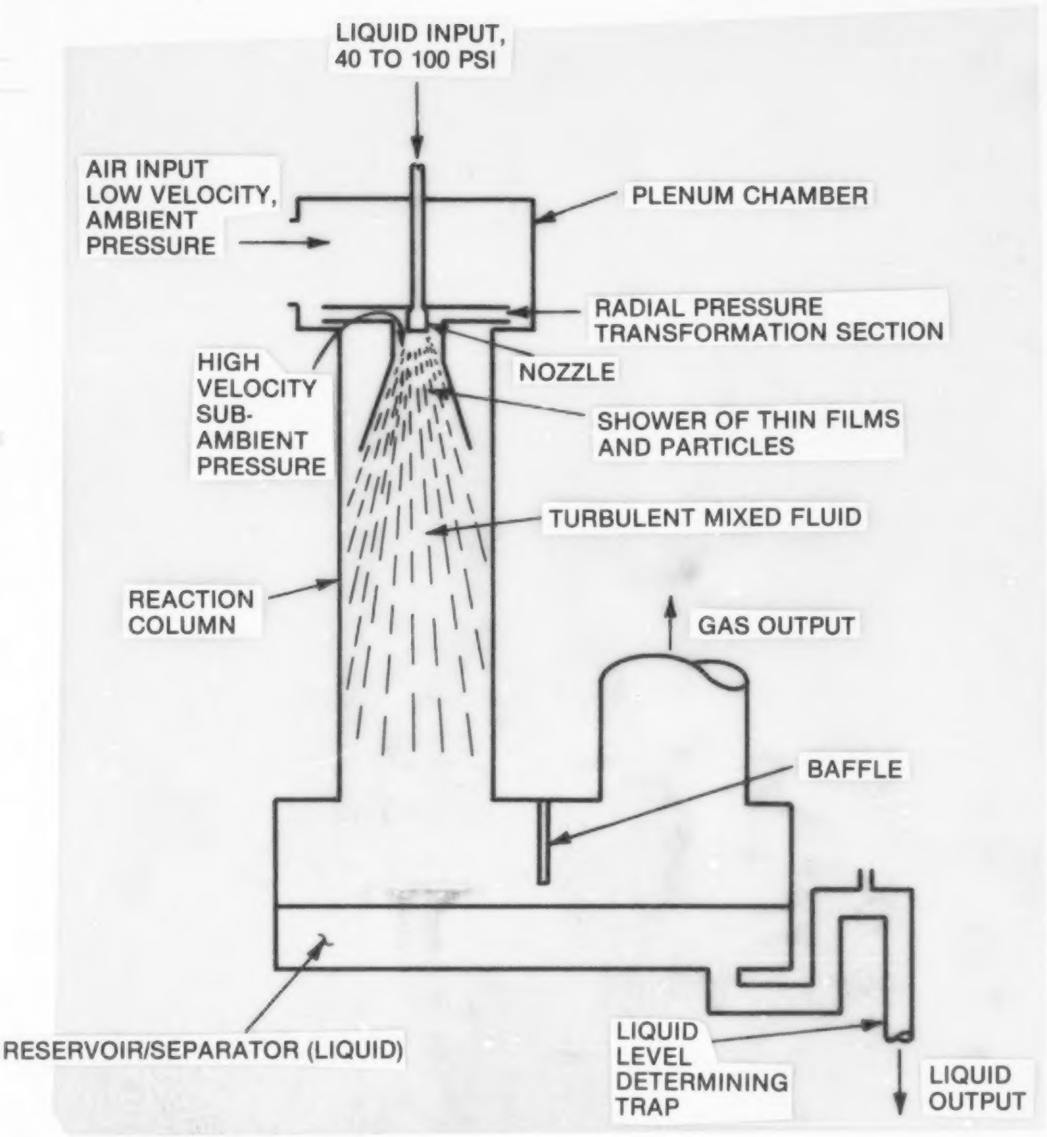
LIQUID INPUT, 40 TO 100 PSI
AIR INPUT LOW VELOCITY, AMBIENT PRESSURE
PLENUM CHAMBER
RADIAL PRESSURE TRANSFORMATION SECTION
HIGH VELOCITY SUB-AMBIENT PRESSURE
NOZZLE
SHOWER OF THIN FILMS AND PARTICLES
TURBULENT MIXED FLUID
REACTION COLUMN
GAS OUTPUT
BAFFLE
RESERVOIR/SEPARATOR (LIQUID)
LIQUID LEVEL DETERMINING TRAP
LIQUID OUTPUT

Figure 28. Dynactor diffusion system cross-sectional view.

The Dynactor can be viewed as a macroscopic diffusion pump that makes use of diffusion principles in order to aspirate large volumes of air per volume of motive liquid. Liquid entering the system under a pressure of 40 to 100 lbs per square inch (typical) is atomized into thin films and droplets of average thickness or diameter less than 1/64 inch. This liquid discharge sprays into the reaction chamber, causing air or gas to be aspirated by being trapped within the moving shower of films and particles. The internal configuration is constructed to maximize gas-liquid turbulence and contact throughout the length of the 6-foot-long, 12-inch-diameter reaction column. The resulting mixed fluid then continues to travel down the reaction column with intimate contact maintained between gas and liquid, causing physical and chemical equilibria to occur by the time the mixed fluid exits from the reaction column and enters the separation reservoir.

In the radial pressure transformation section the partial vacuum that obtains within the Dynactor is produced by accelerating ambient air at low velocity and atmospheric pressure to high velocity and subambient pressure as it enters the reaction column. By utilizing diffusion, the Dynactor aspirates up to 4800 standard volumes of gas per volume of motive liquid. Venturi eductors will aspirate typically in the range of 100 volumes of gas per volume of motive liquid.

The two-stage Dynactor employed during this study used an input of about 5 gpm of water at 100 lbs per square inch pressure. Approximately 2000 standard cubic feet per minute of atmospheric air were aspirated into the Dynactor and contacted with this water under these conditions with power requirements of 1/3 horsepower.

Since the moving liquid in the reaction chamber is essentially a thin film, the gas transfer, mass transfer, and heat transfer reaction rates are extremely rapid.

The Dynactor was equipped with liquid, gas, and powder metering systems, thus enabling stoichiometric quantities of decontaminating agents such as lime, bicarbonate, ozone, acetic acid, and powdered carbon to be introduced into the flow of contaminated water through the Dynactor. Key decontamination reactions that have been accomplished and demonstrated in the Dynactor system can be listed as follows:

1. Aeration
2. Oxidation
3. Ozonation
4. Neutralization
5. Precipitation
6. Carbon adsorption
7. Combination reactions

Since carbon adsorption was to be used in this study to remove traces of soluble creosote before returning the effluent water to the stream, the details of this process will be documented here. Examples of all other decontamination reactions have been reported elsewhere.

The use of powdered carbon (Nuchar 190N) processed by the Dynactor in both slurry and powdered form has been extensively and quantitatively studied in the decontamination of water containing phenol, chlorine, DDT, ethion, toxaphene, and the water-soluble hydrocarbons from fuel oil No. 2. When slurries (10% carbon) are used, they are metered directly into the contaminated water (liquid) input line before passing through the nozzle. Dry powdered carbon is aerosolized by the powder feed mechanism and sucked into the throat of the Dynactor by the air intake under the baffles of the impedance section. The wetting and dispersion of the carbon by the turbulent thin-film contact is excellent at a liquid flowrate of 5 gal per minute and a carbon metering rate of about 15 to 20 grams per minute.

Powdered carbon introduced by the Dynactor will be used to remove the soluble portion of creosote and other hydrocarbons. This will ensure a high-quality effluent to the stream.

The exact amount of carbon needed to remove water-soluble creosote fractions to yield an effluent of satisfactory water quality were determined experimentally. Samples of mud removed from the bottom were thoroughly agitated and the aqueous phase separated by laboratory centrifugation. The soluble and creosote portion was determined gravimetrically by the hexane extraction method before and after carbon treatment.

Secondary Settling Column

The magnetic carbon/water/bottom mud slurry from the reservoir of the Dynactor was pumped to the secondary settling column which was identical in construction to the primary settling column. A high molecular weight polymer flocculant was added to enhance the settling rate. The thickened carbon sludge was continuously bled off through the manually operated valve at the bottom of the settler.

Magnetic Separation of Solids

During another EPA contract (68-01-0123) it was clearly demonstrated that batches of suspended solids, precipitates, and carbon dispersions could be thickened by the formation of a magnetic floc when the proper amounts of magnetic material were mixed with them in the presence of an optimum amount of a polyelectrolyte flocculating agent.

In a mobile field configuration, the decontamination of waterways impacted by spilled hazardous materials usually requires a continuous-flow process to remove potentially toxic precipitates, suspended solids, and spent carbon in suspension.

Suspensions of powdered carbon from the effluent of the Dynactor were very difficult to thicken by state-of-the-art techniques. Flocculating agents were used, and although some of these produced a suitable floc within 2 seconds after addition of about 1 ppm, when the carbon floc was processed in continuous-flow separators or commercial filters, the shear forces were sufficient to disrupt the lacy structure of the carbon floc and incomplete separation resulted. However, when an inexpensive magnetic oxide was added to the suspended carbon in combination with a flocculating agent, the resulting floc became magnetic and could be quantitatively removed in a continuous-flow magnetic separator.

In order to simultaneously remove the magnetic floc of suspended solids and dewater the solids, a particular kind of magnetic separator was used. Sludge from the secondary settling column containing activated carbon, suspended solids (containing creosote) and a polyelectrolyte flocculating agent was allowed to flow by gravity through the orifice or "slice" of the head box under the moving Mylar belt suspended below the magnet structure. The magnetic floc of suspended solids materials was rapidly attracted to the bottom side of the moving belt due to the presence of the magnetic structure suspended above this element. Clarified water flowed down to a sump and could be released back into the stream. Dewatered solids material was continuously scraped off the moving belt after the belt has passed by and away from the magnet structure. Thickened solids, including all remaining stream bed solids, carbon, and magnetic material were collected in plastic barrels and transported to a landfill area designated for the purpose.

Separation of suspended solids in a magnetic floc by the above-described magnetic separator proved rapid, efficient, continuous, and produced an acceptable effluent for release to the river.

Sand Filtration

As shown in Figure 26, the treated water from both the secondary settling column and the magnetic separator was passed thorugh a sand filter before release to the river. The filter, a Hanson Industries type, commonly used as a swimming pool filter, was used to prevent unsettled carbon fines from being discharged along with the treated water.

FIELD DEMONSTRATION

Preparation

Experimental data on the project was developed over a period of 5 months from July through November 1972. Analytical work on all samples was completed and reported in December 1972.

System design, fabrication, and testing were started in July. The gasoline powered screw pump was procured for pumping mud from the stream bottom. The pump, rated at 10.3 gpm, was designed to pump slurries and suspensions. It will pass pebbles and particles up to 3/16-inch in diameter without clogging. It is self-priming, positive displacement and can deliver bottom mud to the treatment system at any practical distance within the contract geography of Phase I. The pump was taken to the Assabet River in Marlboro, Massachusetts, several times in order to conduct performance studies and to better define the mud-sucking equipment problems. It was decided that a narrow slot pickup device was required for effective removal of silt and mud. Velocity is high into the narrow slot pickup device, and essentially no cloud of stirred up bottom sediment escapes. Clogging was experienced with early designs and several redesigns had to be fabricated, eliminating any internal angles and shoulders where mud, grass, and leaveds could impact. An auger was designed and tested, but contributed very little to the efficiency of sediment removal.

During August and September, design and fabrication of the high-rate settling columns, Dynactor system including plenum chamber, reservoir and carbon dispenser, the magnetic separator, premagnetizing section, traps, and suction removal scoop were completed. Tests on effluent from the magnetic separator indicated that the clarified effluent was of sufficient water quality to be returned to the stream.

During August, personnel from R P Industries and Bio-Test made a site visit to the Little Menomonee River with the Project Officer. Several sites along the river were explored and bottom mud samples collected for analysis and settling rate studies. Since a growth of aquatic grass and other vegetation in sections of the river was observed and it was determined that the growth was not in existence at the time the project was formulated, it was agreed that the contractor could spend 2 days in advance site preparation removing debris and pulling out vegetation in advance of the 10 days of assigned bottom cleanup.

In addition, it was observed that any disturbance of the river bottom caused the appearance of an oil slick and the odor of creosote. To prevent this contamination from being carried downstream during cleanup operations, oil absorbent booms (Johns Manville Sea Serpents) were placed across the river downstream from cleanup operations.

Samples of river bottom sediment containing creosote were taken to R P Industries' laboratories and evaluated for settling rate and clarification chatacteristics. Settling speed was substantially slower than anticipated and emulsion formation was encountered due to the presence of creosote. As a result, the primary settling column was redesigned and a high-rate column was substituted for the originally planned conventional system. A modified slanted tube section was designed in order to increase the effective retention time without adding additional volume to the system.

Chemical Coagulation Studies

Since creosote in the river sediment markedly interfered with coagulation and settling, it was considered essential to the program to conduct pertinent laboratory experiments with additional samples of mud to solve the problem of emulsion formation and slow settling.

These studies were performed for Industrial Bio-Test Laboratories at the facilities of its parent company, Nalco Chemical Company, using the extensive industrial water treatment experience of their research and development laboratories group. Sample description of Little Menomonee River bottom mud were deep brown in color, had a pH of 7.0, and the odor of creosote. On centrifugation, they showed 60% water and 40% sediment. A Freon extraction test showed 1.6% extractables. Samples of mud were diluted 9:1 with water to simulate dredge conditions.

Methodology

Fifteen-ml sample tubes were filled with the muddy water, dosed with chemicals, and placed in a rack designed to rotate 40 tubes at a time. After a 10-minute rotation period, the tubes were checked for emulsion breaking activity. Chemicals checked were N-600, N-603, N-634, 7720, 7721, 7722, 7740-A, and D-2366. Of these, 603, 634, and 7722 showed sufficient activity to proceed to jar tests.

Jar tests were performed on each of the three chemicals primarily to observe their coagulation characteristics and water clarify.

Settling times were done by the following method: A 10% mud suspension was prepared and poured through a No. 4 filter screen to remove rocks, sticks, and leaves. This filtered slurry was used to fill 250-ml stoppered graduated cylinders. Each chemical was added in known quantities, and the cylinders were inverted five times. Settling was measured as the time in seconds for the interface to travel 3 inches and then converted to feet per hour.

Settling Test Results

The experimental results are shown in Figure 29 and Table 10. N-634 showed a rapid settling rate at greater than 125 ppm and N-603 showed a maximum effect at 100 ppm by volume. The N-603 gave a cloudy supernatant, whereas the N-634 produced a clean supernatant and a slightly higher settling rate. Freon extractions were made in the supernatant liquid from the jar tests. AT 150 ppm by volume (176 ppm by weight), N-634 gave 10 ppm total extractables by volume, and N-603 at 125 ppm showed 80 ppm extractables. By using N-610 at 10 ppm in addition to N-634 at 150 ppm, significantly higher settling rates were obtained. However, in view of the excellent performance of N-634 the extra cost was not deemed justified. The fact that the supernatant after flocculation with N-634 showed only 10 ppm Freon extractables indicated that most of the creosote will stay with the mud sediment and can be removed by the high-rate settling column.

The flowrate into the primary column was assumed to be 10 gpm, and the addition of 0.03 gpm (114 ml per minute) of a 5% solution of N-634 was recommended.

Field Setup

All of the equipment for cleanup and decontamination of creosote in the river bottom sediment previously described was loaded in a rented truck by R P Industries personnel in Marlboro for departure to Milwaukee on October 9, 1972. Supervisory engineer personnel flew to the site in advance of the equipment arrival.

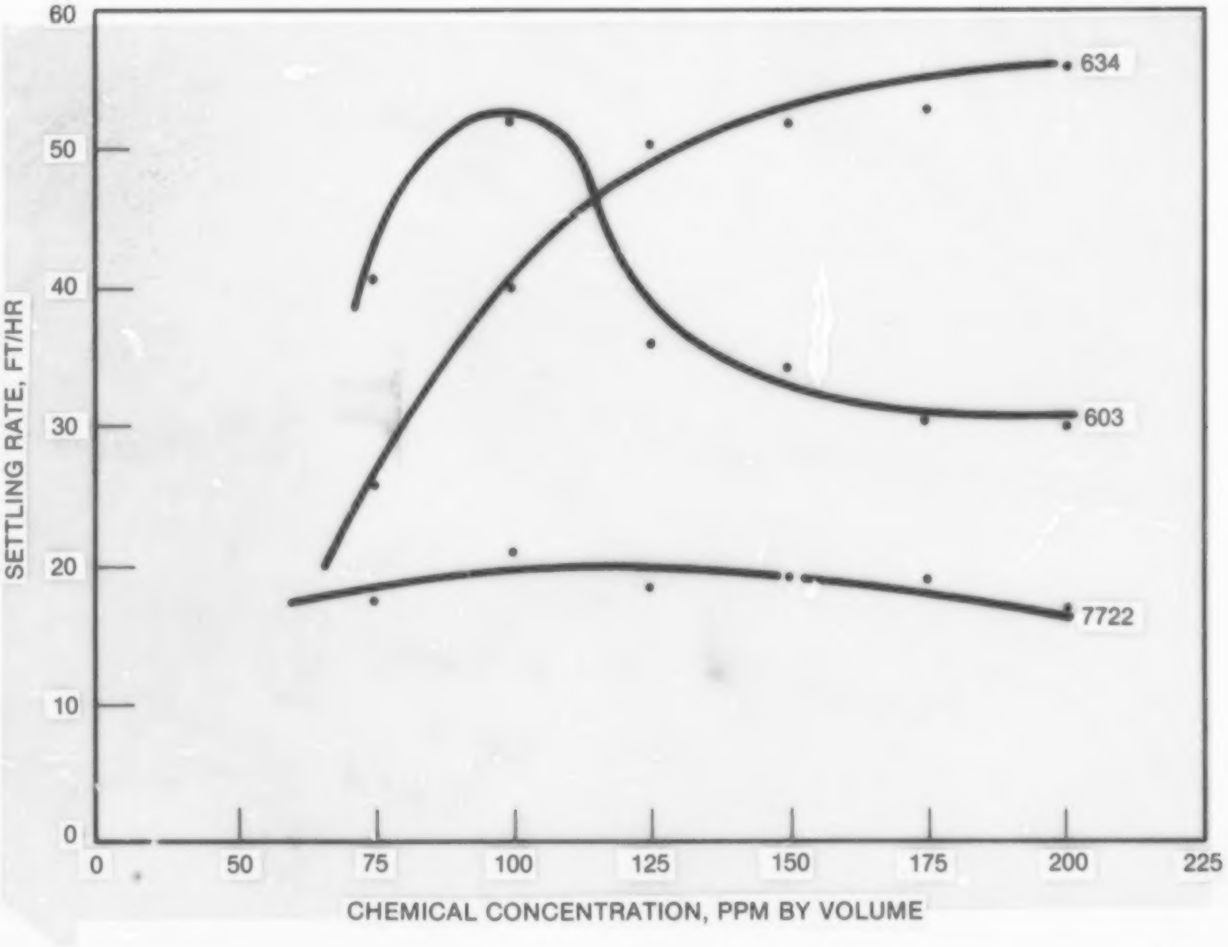

Figure 29. Little Menomonee River floc settling studies.

TABLE 10. RESULTS OF BIO-TEST SETTLING TIME STUDIES

Chemical	Settling Rate (Seconds to go 3 inches)[a]					
	75 ppm	100 ppm	125 ppm	150 ppm	175 ppm	200 ppm
N-634	34.0	22.3	18.0	17.3	17.0	17.0
7722	51.3	41.8	48.0	47.3	48.8	--
N-603	22.0	17.3	24.8	26.0	29.8	--
N-634 + 10 ppm 610[b]	--	--	--	11.5	--	--

a - Average of four runs.

b - Average of two runs.

During the week of October 9, arrangements were made with local vendors to procure services and facilities, including rental of a tent, a gasoline-driven power source, extension ladders to serve as river bridging platforms, sheets of plywood, a wheelbarrow, a sickle-bar grass mower, telephone, night guards from Merchants Police, a Dumpster from Industrial Waste Corp. for removal of sludge and debris to sanitary landfills, a kerosene-fired space heater, kerosene, flexible hose, and miscellaneous hardware items.

Aquatic vegetation, branches and miscellaneous debris were removed from the 500-foot stretch on October 11, 12, and 13, by manual raking. Creosote-contaminated material was placed on polyethylene sheets, rolled up and placed in the Dumpster for disposal. Weeds and grass were cut to provide for a road-path and the location of a tent approximately 24 feet in diameter and 14 feet high to protect the system equipment and workers from the elements. Sections of plywood were used as flooring for the tent to provide walkways and dry storage areas.

The processing equipment was unloaded from the truck at the tent site and set up as shown in the block diagram, Figure 26, on October 11. All of the equipment was interconnected in accordance with the logic table and wiring diagram previously prepared by R P Industries engineers. All equipment was tested for water tightness and operation of electrical components, and the equipment functioned satisfactorily. The portable gas-electric generator provided power in excess of that required to operate all equipment and lights. A telephone was available in the tent, and communiations between the tent and personnel on the river was possible by walky-talky units.

FIELD OPERATIONS

On October 16 initial water and bottom samples were obtained by field personnel from Bio-Test. Standard methods of sampling for water quality analysis were strictly adhered to. Locations of the measurements were taken at the stations and in the manner previously described. samples were immediately taken to Bio-Test Laboratories in Northbrook, Illinois, for analysis.

Actual river bottom removal and system start-up began on the afternoon of October 16. Initial observations on the processing of the creosote containing mud slurry sucked from the river bottom were as follows. The sludge output of the first high-rate settling column was a thick, black mud with a strong odor of creosote. Samples drawn from the mud discharged to the Dumpster showed that consolidated mud predominated. After 3 hours settling time in a glass jar, about 75% of the volume was mud and 25% clear water on top. This was an unexpectedly high solids content and attested to the effectiveness of the primary chemical flocculant selected for the primary settling column.

The supernatant overflow from the first settler appeared as slightly turbid water with a faint odor of creosote and a trace of suspended solids. The Dynactor processed this effluent by adding powdered carbon (Nuchar 190N) containing 15% by weight of magnetic iron oxide. The effluent from the Dynactor appeared as a black suspension of carbon, as expected. This effluent flows through the second high-rate settling column after addition of 1 ppm of a high molecular weight polymer to floc the magnetic carbon. The overflow effluent was essentially clear water with no odor and a very slight gray tinge. This effluent was then passed through a sand filter, resulting in a crystal-clear water which subsequent analysis showed to have less than 0.1 ppm hexane extractables and 12 mg/l suspended solids.

The thickened carbon from the underflow of the second settler was pumped to the continuous-flow magnetic separator yielding a dewatered sludge and a clear effluent that was likewise passed through the sand filter and returned to the river.

On October 17 a sudden early morning "hard freeze" caused ice formation in the hoseline which required half a day to unclog. A continuation of the cold snap into October 18, 19, and 20 caused operations to be limited to 5 hours on each of those days. At this point in time, progress on river bottom cleaning was estimated at about 190 square feet per hour.

On October 21 and 22 up to 3 inches of rain fell in the area and limited operations to half-days. Rain and runoff was washing mud and silt and creosote back into the stream from the river banks. The roadway was impassable and working conditions were very difficult. On October 23 the river flooded and all operations had to be suspended. Working in the area was becoming dangerous, and the rising water threatened to inundate the tent and equipment. On October 24, operations were suspended and emergency measures were taken to protect the equipment until river conditions returned to normal. Security and consulting personnel remained at the site, while operations personnel returned to their respective offices. From October 26 through October 30, daily checks were made by phone on weather and river conditions. The operating personnel returned to the site on October 31 and spent the balance of the day cleaning up from the flood and getting the equipment into operation condition again.

Operations resumed on November 1 and continued on a relatively routine basis with the 140 square foot per hour rate maintained for the next 4 days. This rate included removal of creosote from heavy pockets that were encountered. Cleanup operations were completed during the morning of November 5.

On November 3 and 5 a limited number of bottom samples were taken as representative of mid-core sampling. The bottom sediments were taken in midstream, station 2 at transects 1, 2, 4, and 8, on November 3, 1972, and November 5, 1972.

A complete sampling identical to the "zero time sampling" protocol was conducted on November 6, 25 hours after final cleanup operations.

SECTION 7

INDUSTRIAL BIO-TEST RESULTS AND DISCUSSION

SAMPLING POINTS, PROCEDURES, AND ANALYTICAL METHODS

Sampling and analyses for suspended solids and hexane extractables were performed at various points in the pickup and treatment process to determine the effectiveness of the individual unit processes in producing a good quality effluent for return to the river. The sample locations are listed below:

Raw Flow
Effluent from Primary Settling Column
Effluent from Dynactor
Effluent from Secondary Settling Column
Effluent from Magnetic Separator
Effluent from Sand Filter

As required by the contract, sampling and analyses of river water quality and bottom mud contamination were performed before, during, and after the actual field operations to determine the effectiveness and environmental impact of the bottom cleanup.

Analytical Method

All applicable methods were done according to standard methods. Since no standard method was available for creosote, a modification of 209A, Soxhlet Extraction Method for Grease Determination (Standard Methods for the Examination of Water and Wastewater, 13th ed., American Public Health Association, Washington, DC, 1971) was used.

DISCUSSION OF TREATMENT PROCESS

Each of the unit processes employed contributed toward the production of water effluent highly suitable for discharge to the river. Table 11 summarizes the creosote removal effectiveness of each process and of the total system, while Table 12 furnishes similar information regarding suspended solids removal. The data presented in these tables are typical of the results obtained during the 10 days of Phase I operations. Table 11 shows the effective performance of the Bio-Test/R P system in removing creosote from the influent mud slurry pumped from the bottom of the river. The influent samples had creosote (hexane extractables) levels of approximately 240 mg/l. The primary settling column produced an overflow effluent of 9.1 mg/l, which was further processed by carbon adsorption in the Dynactor to the point where the creosote could

TABLE 11. INDUSTRIAL BIO-TEST/R P INDUSTRIES TREATMENT SYSTEM: CREOSOTE REMOVAL EFFECTIVENESS

Item	Influent (mg/l) Creosote[a]	Effluent (mg/l) Creosote[a]	% of Remaining Creosote Removed	% of Total Creosote Removed	Cumulative % of Creosote Removed
Primary settling column	240.0	9.1	96	96.0	96
Dynactor	9.1	0.1	99+	3.8	99+
Secondary settling column	0.1	0.1	-	-	99+
Magnetic separator	0.1	0.1	-	-	99+
Sand filter	0.1	0.1	-	-	99+
Total system	240.0	0.1	-	99+	99+

a - As determined by hexane extractables method.

TABLE 12. INDUSTRIAL BIO-TEST/R P INDUSTRIES TREATMENT SYSTEM: SUSPENDED SOLIDS REMOVAL EFFECTIVENESS

Item	Influent (mg/l) Suspended Solids	Effluent (mg/l) Suspended Solids	% of Remaining Suspended Solids Removed	% of Total Suspended Solids Removed	Cumulative % of Suspended Solids Removed
Primary settling column	48,000	560	99	99	99
Dynactor	560	1,600	--	(-2.2)[a]	96+
Secondary settling column	1,600	15[b]	99+	3.20	99+
Magnetic separator	20,000	15[c]	--	--	99+
Sand filter	15	10	33	0.01	99+
Total system	48,000	10	--	99+	99+

a - Approximately 1000 mg/l of carbon/iron oxide mixture introduced in this process.

b - Spent carbon, iron oxide, and mud removed in this process.

c - Approximately 20,000 mg/l of sludge from secondary settling column (underflow) dewatered in this process.

barely be detected, that is, less than 0.1 mg/l. Table 12 indicates that 99% of the suspended solids in the influent river bottom mud/creosote slurry (48,000 mg/l) was removed by the first high-rate settling column. Additional solids (1000 mg/l), however, were introduced into the Dynactor in the form of activated carbon (to adsorb the creosote) and iron oxide (to facilitate the magnetic separation of the carbon). This material, plus the residual suspended solids from the effluent of the primary settler, were further processed in the secondary settling column where more than 99% of these solids were concentrated into a sludge (20,000 mg/l) which was further dewatered to 150,000 mg/l in the magnetic separator and subsequently disposed of in the approved landfill. The clarified water effluents from both the secondary settler and the magnetic separator (each having a solids content of 15 mg/l) were passed through the sand filter for final polishing to a suspended solids content of not more than 10 mg/l. This high-quality effluent, indicated above to be essentially free of hexane extractables, was returned to the river.

CHARACTERIZATION OF RIVER WATER AND BOTTOM MUDS

Sampling Methodology and Equipment

Before, during, and after cleanup, sampling was conducted at locations along the designated 500-foot section. These "locations" were at approximately 100-foot-length intervals. There were "sampling stations" at 5-foot-wide intervals at each "loation" starting 2 feet from the near bank. In addition, sampling was done at locations approximately 200 feet upstream from the start of the section and 400 feet downstream from the end of the section. Bottom samples were taken at each station and water column samples were taken at 1-foot-depth intervals starting 3 inches from the bottom and ending 3 inches from the surface. The total number of bottom samples taken was 65. The number of water samples was 195.

All analytical procedures were performed as specified and previously described. Figure 30 shows the details of the geographic and sampling locations for the Little Menomonee River Project. All physical and water quality data are shown as individual values in Tables 13 through 16.

The low air temperature recorded at Mitchell Field was 24°F, and the high was 63°F during the period of operations. A low of 17°F was recorded at the cleanup site. The total precipitation for the period was 3.24 inches, and precipitation was recorded on 12 of the 22 days of operation.

River Water Characterization

All of the individual data was studied for meaningful differences and trends. The data for physical and water quality measurements at each sampling station was totaled and averaged for the initial (October 16, 1972) and final (November 6, 1972) sampling periods to characterize any marked changes in these parameters during the cleanup operations. These averages are summarized in Table 17.

Other than physical changes caused by rainfall and cold weather, there were no significant or marked shifts in water quality related to the cleanup operations.

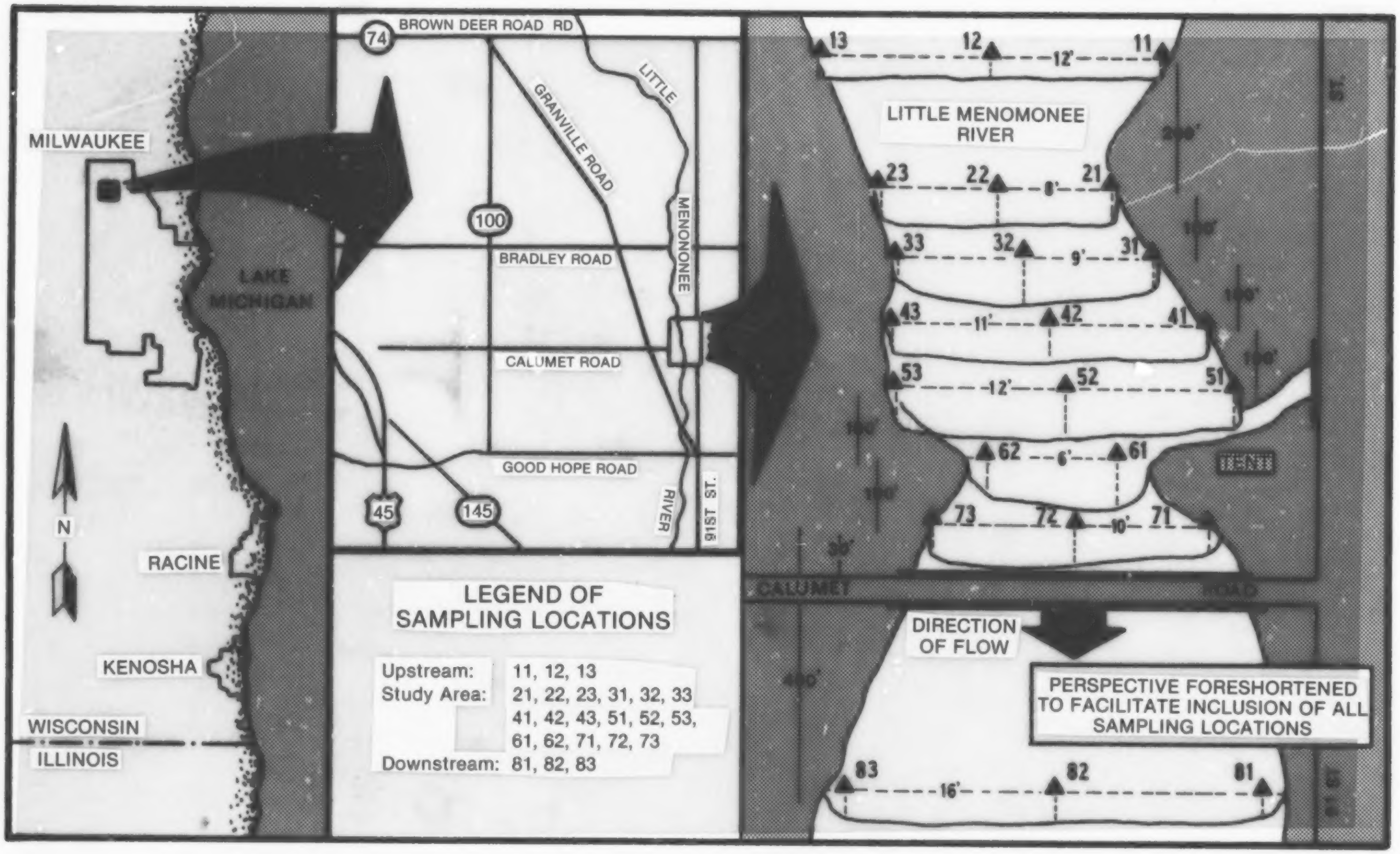
MILWAUKEE
LAKE MICHIGAN
RACINE
KENOSHA
WISCONSIN
ILLINOIS
N
74
BROWN DEER ROAD RD
GRANVILLE ROAD
LITTLE
MENOMONEE
RIVER
100
BRADLEY ROAD
CALUMET ROAD
GOOD HOPE ROAD
91ST ST.
45
145
LEGEND OF SAMPLING LOCATIONS
Upstream: 11, 12, 13
Study Area: 21, 22, 23, 31, 32, 33, 41, 42, 43, 51, 52, 53, 61, 62, 71, 72, 73
Downstream: 81, 82, 83
LITTLE MENOMONEE RIVER
13
12
11
12'
23
22
21
8'
33
32
31
9'
43
42
41
11'
53
52
51
12'
62
61
6'
73
72
71
10'
200'
100'
100'
100'
100'
100'
30'
400'
CALUMET
ROAD
DIRECTION OF FLOW
PERSPECTIVE FORESHORTENED TO FACILITATE INCLUSION OF ALL SAMPLING LOCATIONS
83
82
81
16'

Figure 20. Monitoring sample locations for sediment and water quality, Little Menomonee River.

TABLE 13. WEATHER DATA, LITTLE MENOMONEE RIVER

			Parameters					
			Air Temperature					
Sampling Transect	Date 1972	Time	Wet Bulb, °C	Dry Bulb, °C	Relative Humidity, %	Wind Velocity, mph	Wind Direction	Cloud Cover, %
1	10-16	1930	7.2	11.7	52	4-5	NW	0
1	11-3	1145	5.0	5.6	91	0-2	N	100
1	11-5	1140	7.8	10.6	68	4-5	S	70
1	11-6	1245	8.9	12.8	60	3-4	SW	100
2	10-16	1755	7.2	13.9	45	8-9	W	0
2	11-3	1130	5.0	6.1	84	3-5	N	100
2	11-5	1110	8.3	11.7	63	5-6	S	60
2	11-6	1313	9.4	13.3	60	4-5	SW	100
3	10-16	1700	9.4	16.1	40	8-9	W	0
3	11-6	1351	9.4	12.2	69	3-5	SW	100
4	10-16	1605	10.0	16.7	40	8-9	W	0
4	11-3	1100	5.0	5.6	91	0-2	N	100
4	11-5	1020	6.7	8.3	75	4-5	S	80
4	11-6	1435	8.9	11.1	75	5-8	SW	100
5	10-16	1500	11.1	17.2	47	8-9	W	0
5	11-6	1522	7.8	10.0	74	4-6	SE	100
6	10-16	1345	11.7	17.2	51	7	W	0
6	11-6	1615	7.8	8.9	87	0-1	SE	100
7	10-16	1200	10.6	15.0	58	10	SW	0
7	11-6	1650	7.2	9.4	74	2-3	SE	100
8	10-16	1005	9.4	10.6	86	8-10	NW	0
8	11-3	1230	5.0	6.1	84	4-5	N	100
8	11-5	1300	7.8	11.1	62	3-5	S	30
8	11-6	1815	7.8	9.4	82	0-3	SE	100

TABLE 14. PHYSICAL DATA, LITTLE MENOMONEE RIVER

Sampling Stations[a]	Date, 1972	Parameters	
		Secchi Disc, in.	Depth, in.
11	10-16	b	10.0
11	11-6	13.0	13.0
12	10-16	b	12.0
12	11-3	17.0	17.0
12	11-5	19.0	19.0
12	11-6	18.0	18.0
13	10-16	b	10.5
13	11-6	11.0	11.0
21	10-16	17.0	19.5
21	11-6	20.0	25.0
22	10-16	18.0	20.0
22	11-3	17.0	28.0
22	11-5	27.0	27.0
22	11-6	16.0	28.0
23	10-16	17.0	18.0
23	11-6	18.0	23.0
31	10-16	18.0	18.0
31	11-6	17.0	31.0
32	10-16	18.0	28.0
32	11-6	20.0	34.0
33	10-16	17.0	17.0
33	11-6	18.0	23.0
41	10-16	17.0	17.0
41	11-6	20.0	24.0
42	10-16	21.0	21.0
42	11-3	18.0	28.0
42	11-5	28.0	28.0
42	11-6	21.0	28.0
43	10-16	17.0	17.0
43	11-6	19.0	23.0
51	10-16	15.0	18.0
51	11-6	21.0	23.0

(continued)

TABLE 14 (Continued)

Sampling Stations[a]	Date, 1972	Parameters Secchi Disc, in.	 Depth, in.
52	10-16	20.0	28.0
52	11-6	23.0	32.0
53	10-16	20.0	23.0
53	11-6	21.0	26.0
61	10-16	20.0	29.0
61	11-6	18.0	28.0
62	10-16	22.0	22.0
62	11-6	19.0	28.0
63	c	-	-
63	-	-	-
71	10-16	12.0	12.0
71	11-6	20.0	24.0
72	10-16	17.0	22.0
72	11-6	21.0	34.0
73	10-16	17.0	20.0
73	11-6	20.0	33.0
81	10-16	14.0	14.0
81	11-6	b	12.0
82	10-16	16.0	18.0
82	11-3	18.0	22.0
82	11-5	22.0	22.0
82	11-6	b	18.0
83	10-16	13.0	13.0
83	11-6	b	18.0

a - The first digit of the sampling station is the transect number. The second digit is the station number in the respective transect starting with one on the east bank and increasing going west.

b - The Secchi Disc reading could not be taken due to darkness.

c - Sampling Station 63 was eliminated due to the 6-foot width of the river making a third station in transect 6 impractical according to the contract.

TABLE 15. PRECIPITATION AND HIGH AND LOW AIR TEMPERATURES, LITTLE MENOMONEE RIVER

Date, 1972	High Air Temperature, °F [a]	Low Air Temperature, °F [a]	Precipitation, inches[a]
10-16	63	38	0.00
10-17	42	31	0.00
10-18	41	29	0.00
10-19	43	24	0.00
10-20	49	25	0.15
10-21	48	41	0.45
10-22	51	47	1.68
10-23	51	39	0.45
10-24	43	30	0.06
10-25	51	30	0.00
10-26	58	40	0.00
10-27	53	38	0.03
10-28	49	44	0.17
10-29	44	39	0.00
10-30	46	39	0.00
10-31	44	42	0.05
11-1	47	43	0.02
11-2	55	42	0.15
11-3	45	39	0.01
11-4	41	36	0.00
11-5	51	39	0.00
11-6	52	36	0.02

a - Data obtained from General William Mitchell Field, Milwaukee, Wisconsin.

TABLE 16. LITTLE MENOMONEE RIVER, WATER QUALITY DATA - BIO-TEST SEGMENT

		Parameters				
Sampling Stations[a]	Date, 1972	Temperature, °C	Oxygen Dissolved, mg/l	Oxygen Saturation, %	pH	Turbidity, J.T.U.
11a	10-16	11.0	8.7	78	7.8	18
11b	10-16	b	b	b	b	b
11c	10-16	11.0	8.7	78	7.8	22
11a	11-6	8.0	9.1	76	7.6	16
11b	11-6	b	b	b	b	b
11c	11-6	8.0	9.2	77	7.6	21
12a	10-16	11.0	8.7	78	7.8	23
12b	10-16	b	b	b	b	b
12c	10-16	11.0	8.7	78	7.8	18
12a	11-3	c	c	c	c	c
12b	11-3	8.5	7.9	65	7.7	15
12c	11-3	c	c	c	c	c
12a	11-5	c	c	c	c	c
12b	11-5	8.1	8.4	71	7.7	8
12c	11-5	c	c	c	c	c
12a	11-6	8.0	9.1	76	7.8	24
12b	11-6	b	b	b	b	b
12c	11-6	8.0	9.0	76	7.7	14
13a	10-16	11.0	8.7	78	7.8	37
13b	10-16	b	b	b	b	b
13c	10-16	11.0	8.7	78	7.8	29
13a	11-6	8.0	9.0	76	7.8	20
13b	11-6	b	b	b	b	b
13c	11-6	8.0	8.9	75	7.7	29
21a	10-16	11.0	8.7	78	7.8	17
21b	10-16	11.0	8.7	78	7.8	19
21c	10-16	11.1	8.7	78	7.8	16
21a	11-6	8.7	8.4	72	7.7	19
21b	11-6	8.7	8.4	72	7.6	18
21c	11-6	8.7	8.3	71	7.6	17
22a	10-16	11.1	8.7	78	7.8	18
22b	10-16	11.1	8.7	78	7.8	21
22c	10-16	11.1	8.7	78	7.8	16
22a	11-3	c	-	-	-	-
22b	11-3	8.5	7.7	66	7.7	11
22c	11-3	-	-	-	-	-
22a	11-5	-	-	-	-	-
22b	11-5	8.1	8.4	71	7.7	8
22c	11-5	-	-	-	-	-

(continued)

TABLE 16 (Continued)

Sampling Stations[a]	Date, 1972	Parameters				
		Temperature, °C	Oxygen Dissolved, mg/l	Oxygen Saturation, %	pH	Turbidity, J.T.U.
22a	11-6	8.7	8.2	70	7.7	15
22b	11-6	8.7	8.2	70	7.6	17
22c	11-6	8.7	8.1	69	7.7	16
23a	10-16	11.0	8.7	78	7.8	21
23b	10-16	11.1	8.7	78	7.8	14
23c	10-16	11.0	8.7	78	7.8	25
23a	11-6	8.7	8.0	68	7.5	20
23b	11-6	8.7	7.5	65	7.6	18
23c	11-6	8.7	7.5	65	7.7	22
31a	10-16	11.5	8.5	77	7.8	19
31b	10-16	11.5	8.5	77	7.8	15
31c	10-16	11.5	8.5	77	7.8	17
31a	11-6	8.7	8.7	74	7.6	25
31b	11-6	8.7	8.6	73	7.5	20
31c	11-6	8.5	8.6	73	7.5	34
32a	10-16	11.5	8.5	77	7.8	15
32b	10-16	11.5	8.5	77	7.8	15
32c	10-16	11.5	8.5	77	7.8	15
32a	11-6	8.7	8.6	73	7.7	19
32b	11-6	8.7	8.4	72	7.5	18
32c	11-6	8.7	8.4	72	7.7	22
33a	10-16	11.5	8.5	77	7.8	22
33b	10-16	11.5	8.5	77	7.8	14
33c	10-16	11.3	8.6	78	7.8	17
33a	11-6	8.7	8.3	71	7.5	17
33b	11-6	8.7	8.2	70	7.7	34
33c	11-6	8.7	8.1	69	7.7	28
41a	10-16	11.0	8.4	76	7.6	28
41b	10-16	11.0	8.4	76	7.8	20
41c	10-16	11.0	8.4	76	7.8	60
41a	11-6	9.0	8.2	71	7.7	14
41b	11-6	9.0	8.3	72	7.6	19
41c	11-6	9.0	8.4	72	7.7	14
42a	10-16	11.0	8.5	77	7.8	16
42b	10-16	11.0	8.4	76	7.8	23
42c	10-16	11.0	8.4	76	7.8	16

(continued)

TABLE 16 (Continued)

Sampling Stations[a]	Date, 1972	Parameters Temperature, °C	Oxygen Dissolved, mg/l	Oxygen Saturation, %	pH	Turbidity, J.T.U.
42a	11-3	c	-	-	-	-
42b	11-3	8.4	7.8	66	7.8	14
42c	11-3	-	-	-	-	-
42a	11-5	-	-	-	-	-
42b	11-5	7.8	8.3	69	7.7	9
42c	11-5	-	-	-	-	-
42a	11-6	9.0	8.4	72	7.7	13
42b	11-6	9.3	8.4	73	7.7	17
42c	11-6	9.3	8.4	73	7.7	17
43a	10-16	10.9	8.4	76	7.8	14
43b	10-16	10.9	8.4	76	7.8	16
43c	10-16	10.9	8.4	76	7.8	15
43a	11-6	9.3	8.3	72	7.7	21
43b	11-6	9.3	8.2	71	7.6	18
43c	11-6	9.3	8.2	71	7.6	25
51a	10-16	10.9	8.2	74	7.8	23
51b	10-16	10.9	8.2	74	7.8	16
51c	10-16	10.9	8.2	74	7.8	24
51a	11-6	8.5	7.3	62	7.7	34
51b	11-6	8.5	7.3	62	7.7	21
51c	11-6	8.5	7.2	62	7.7	35
52a	10-16	11.0	8.3	75	7.8	17
52b	10-16	10.9	8.2	74	7.8	24
52c	10-16	10.9	8.2	74	7.8	18
52a	11-6	8.5	7.3	62	7.6	17
52b	11-6	8.5	7.3	62	7.7	18
52c	11-6	8.5	7.2	62	7.7	16
53a	10-16	11.0	8.2	74	7.8	18
53b	10-16	11.0	8.2	74	7.8	22
53c	10-16	11.0	8.2	74	7.8	23
53a	11-6	8.5	7.2	62	7.6	17
53b	11-6	8.5	7.2	62	7.7	15
53c	11-6	8.5	7.2	62	7.7	18
61a	10-16	10.1	8.2	73	7.8	15
61b	10-16	10.1	8.2	73	7.8	12
61c	10-16	10.0	8.2	73	7.8	14
61a	11-6	9.0	7.2	62	7.7	16
61b	11-6	9.0	7.1	61	7.7	19

(continued)

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TABLE 16 (Continued)

Sampling Stations[a]	Date, 1972	Parameters				
		Temperature, °C	Oxygen Dissolved, mg/l	Oxygen Saturation, %	pH	Turbidity, J.T.U.
61c	11-6	9.0	7.0	60	7.7	16
62a	10-16	10.0	7.9	73	7.8	14
62b	10-16	10.0	7.9	73	7.8	13
62c	10-16	10.0	8.0	73	7.8	14
62a	11-6	9.0	6.9	59	7.7	15
62b	11-6	9.0	6.9	59	7.7	17
62c	11-6	9.0	7.0	60	7.7	16
63a	d	-	-	-	-	-
63b	-	-	-	-	-	-
63c	-	-	-	-	-	-
63a	-	-	-	-	-	-
63b	-	-	-	-	-	-
63c	-	-	-	-	-	-
71a	10-16	8.9	8.0	69	7.8	25
71b	10-16	-	-	-	-	-
71c	10-16	8.9	8.0	69	7.7	17
71a	11-6	9.0	6.8	59	7.7	18
71b	11-6	-	-	-	-	-
71c	11-6	9.0	6.8	57	7.7	27
72a	10-16	8.9	8.0	69	7.7	13
72b	10-16	8.9	8.0	69	7.8	14
72c	10-16	8.9	8.0	69	7.8	16
72a	11-6	9.0	6.6	57	7.7	15
72b	11-6	9.0	6.6	57	7.7	14
72c	11-6	9.0	6.6	57	7.7	13
73a	10-16	8.9	8.0	69	7.8	16
73b	10-16	8.9	8.0	69	7.8	13
73c	10-16	8.9	8.0	69	7.8	12
73a	11-6	9.0	6.6	57	7.7	18
73b	11-6	9.0	6.7	58	7.7	13
73c	11-6	9.0	6.7	58	7.7	14
81a	10-16	8.0	7.9	66	7.8	12
81b	10-16	b	b	b	b	b
81c	10-16	8.0	7.9	66	7.8	15
81a	11-6	9.0	7.8	67	7.6	20
81b	11-6	b	b	b	b	b
81c	11-6	8.9	7.8	67	7.7	14

(continued)

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TABLE 16 (Continued)

Sampling Stations[a]	Date, 1972	Parameters: Temperature, °C	Oxygen Dissolved, mg/l	Oxygen Saturation, %	pH	Turbidity, J.T.U.
82a	10-16	8.0	7.9	66	7.8	13
82b	10-16	7.9	7.8	66	7.8	12
82c	10-16	7.9	7.8	66	7.8	13
82a	11-3	c	c	c	c	c
82b	11-3	8.5	8.3	72	7.8	17
82c	11-3	c	c	c	c	c
82a	11-5	c	c	c	c	c
82b	11-5	8.8	9.3	79	7.8	8
82c	11-5	c	c	c	c	c
82a	11-6	8.5	7.7	66	7.5	16
82b	11-6	8.8	7.8	66	7.5	15
82c	11-6	8.8	7.8	66	7.7	13
83a	10-16	7.5	7.7	64	7.8	13
83b	10-16	b	b	b	b	b
83c	10-16	7.9	7.7	66	7.8	13
83a	11-6	9.0	8.2	71	7.7	14
83b	11-6	b	b	b	b	b
83c	11-6	9.0	8.1	70	7.7	15

(continued)

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TABLE 16 (Continued)

		Parameters					
Sampling Stations[a]	Date, 1972	Ammonia mg/l-N	Nitrate mg/l-N	Sol., Ortho-phosphate mg/l-P	Organic Carbon, Total mg/l	Specific Conductance µmhos/cm	Solids, Suspended mg/l
11a	10-16	0.12	2.73	0.021	20	1111	43
11b	10-16	b	b	b	b	b	b
11c	10-16	0.13	2.54	0.020	20	1128	52
11a	11-6	0.09	2.78	0.024	37	972	17
11b	11-6	b	b	b	b	b	b
11c	11-6	0.09	2.83	0.023	25	967	32
12a	10-16	0.11	2.96	0.019	33	1111	53
12b	10-16	c	c	c	c	c	c
12c	10-16	0.12	3.08	0.019	28	1108	27
12b	11-3	0.06	2.07	0.016	18	874	28
12c	11-3	c	c	c	c	c	c
12a	11-5	c	c	c	c	c	c
12b	11-5	0.08	2.35	0.029	32	953	24
12c	11-5	c	c	c	c	c	c
12a	11-6	0.09	2.59	0.023	43	971	36
12b	11-6	c	c	c	c	c	c
12c	11-6	0.12	3.17	0.023	35	970	12
13a	10-16	0.12	3.11	0.019	27	1274	23
13b	10-16	b	b	b	b	b	b
13c	10-16	0.06	3.00	0.021	25	1102	46
13a	11-6	0.09	2.99	0.023	40	972	26
13b	11-6	b	b	b	b	b	b
13c	11-6	0.12	2.76	0.024	25	969	42
21a	10-16	0.11	2.76	0.022	29	1101	32
21b	10-16	0.12	3.08	0.019	48	1099	23
21c	10-16	0.11	2.54	0.020	18	1115	17

(continued)

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TABLE 16 (Continued)

Sampling Stations[a]	Date, 1972	Parameters					
		Ammonia mg/1-N	Nitrate mg/1-N	Sol., Ortho-phosphate mg/1-P	Organic Carbon, Total mg/1	Specific Conductance µmhos/cm	Solids, Suspended mg/1
21a	11-6	0.09	2.61	0.024	22	972	18
21b	11-6	0.09	2.99	0.023	23	972	18
21c	11-6	0.09	2.99	0.022	26	973	18
22a	10-16	0.12	2.20	0.016	22	1112	200
22b	10-16	0.12	2.40	0.018	32	1106	120
22c	10-16	0.12	2.40	0.022	18	1100	101
22a	11-3	c	-	-	-	-	-
22b	11-3	0.07	2.22	0.016	23	876	38
22c	11-3	-	-	-	-	-	-
22a	11-5	-	-	-	-	-	-
22b	11-5	0.09	2.70	0.029	45	952	22
22c	11-5	-	-	-	-	-	-
22a	11-6	0.10	2.78	0.025	38	970	16
22b	11-6	0.09	2.99	0.024	36	968	12
22c	11-6	0.08	3.68	0.023	28	968	14
23a	10-16	0.12	2.10	0.022	18	1105	20
23b	10-16	0.13	2.92	0.018	26	1107	15
23c	10-16	0.11	3.11	0.016	22	1112	7
23a	11-6	0.10	2.91	0.022	30	975	19
23b	11-6	0.09	2.48	0.023	25	970	16
23c	11-6	0.09	3.17	0.023	37	968	17
31a	10-16	0.11	2.92	0.017	38	1112	35
31b	10-16	0.06	2.48	0.018	32	1126	22
31c	10-16	0.06	3.18	0.018	25	1097	19
31a	11-6	0.08	2.58	0.023	43	970	14
31b	11-6	0.08	2.38	0.025	38	972	10
31c	11-6	0.08	2.78	0.024	28	973	7

(continued)

TABLE 16 (Continued)

Sampling Stations[a]	Date, 1972	Parameters Ammonia mg/l-N	Nitrate mg/l-N	Sol., Ortho-phosphate mg/l-P	Organic Carbon, Total mg/l	Specific Conductance µmhos/cm	Solids, Suspended mg/l
32a	10-16	0.12	2.76	0.018	20	1118	17
32b	10-16	0.12	2.40	0.018	19	1116	10
32c	10-16	0.12	2.40	0.017	22	1108	7
32a	11-6	0.07	2.38	0.023	27	973	30
32b	11-6	0.08	2.38	0.025	37	972	14
32c	11-6	0.08	2.31	0.024	26	969	18
33a	10-16	0.12	3.08	0.016	37	1125	22
33b	10-16	0.12	2.80	0.016	24	1116	38
33c	10-16	0.12	2.92	0.017	31	1106	13
33a	11-6	0.08	2.75	0.023	25	970	12
33b	11-6	0.08	2.99	0.025	29	970	18
33c	11-6	0.07	2.52	0.025	36	968	14
41a	10-16	0.06	2.68	0.016	25	1122	27
41b	10-16	0.06	2.61	0.017	41	1101	17
41c	10-16	0.06	2.92	0.015	46	1103	111
41a	11-6	0.07	3.38	0.024	34	921	28
41b	11-6	0.07	3.17	0.023	38	968	28
41c	11-6	0.08	2.58	0.024	25	983	28
42a	10-16	0.12	2.40	0.016	20	1106	20
42b	10-16	0.13	2.92	0.016	37	1102	20
42c	10-16	0.13	2.76	0.017	22	1121	20
42a	11-3	c	-	-	-	-	-
42b	11-3	0.08	2.35	0.015	15	873	30
42c	11-3	-	-	-	-	-	-
42a	11-5	-	-	-	-	-	-
42b	11-5	0.09	5.32	0.027	24	951	33
42c	11-5	-	-	-	-	-	-

(continued)

TABLE 16 (Continued)

Sampling Stations[a]	Date, 1972	Parameters					
		Ammonia mg/l-N	Nitrate mg/l-N	Sol., Ortho-phosphate mg/l-P	Organic Carbon, Total mg/l	Specific Conductance μmhos/cm	Solids, Suspended mg/l
42a	11-6	0.08	2.61	0.024	27	986	24
42b	11-6	0.08	2.45	0.023	35	979	46
42c	11-6	0.07	2.41	0.024	18	976	36
43a	10-16	0.07	2.76	0.016	37	1118	22
43b	10-16	0.12	3.00	0.017	24	1122	18
43c	10-16	0.06	2.96	0.017	19	1124	15
43a	11-6	0.07	3.20	0.023	28	965	44
43b	11-6	0.08	2.31	0.023	36	972	106
43c	11-6	0.08	3.08	0.021	45	973	138
51a	10-16	0.10	3.08	0.017	18	1123	30
51b	10-16	0.11	2.88	0.017	20	1120	21
51c	10-16	0.13	2.92	0.016	26	1125	17
51a	11-6	0.07	2.99	0.024	38	968	70
51b	11-6	0.07	3.16	0.024	31	974	46
51c	11-6	0.09	2.55	0.023	26	971	50
52a	10-16	0.06	2.73	0.017	23	1118	26
52b	10-16	0.07	2.61	0.016	24	1152	21
52c	10-16	0.13	3.18	0.016	32	1170	14
52a	11-6	0.08	2.58	0.024	26	972	36
52b	11-6	0.08	2.20	0.024	25	975	26
52c	11-6	0.08	2.78	0.024	29	978	30
53a	10-16	0.12	3.30	0.015	21	1126	26
53b	10-16	0.12	3.58	0.017	26	1122	26
53c	10-16	0.12	3.33	0.017	41	1124	26
53a	11-6	0.08	1.92	0.024	35	972	24
53b	11-6	0.08	2.34	0.024	40	972	22
53c	11-6	0.08	2.28	0.024	27	974	32

(continued)

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TABLE 16 (Continued)

Sampling Stations[a]	Date, 1972	Parameters Ammonia mg/l-N	Nitrate mg/l-N	Sol., Ortho-phosphate mg/l-P	Organic Carbon, Total mg/l	Specific Conductance µmhos/cm	Solids, Suspended mg/l
61a	10-16	0.12	3.33	0.016	19	1116	21
61b	10-16	0.12	3.13	0.015	25	1116	19
61c	10-16	0.14	3.33	0.016	32	1128	10
61a	11-6	0.09	2.20	0.025	22	969	16
61b	11-6	0.09	2.52	0.024	26	971	18
61c	11-6	0.09	2.96	0.024	26	972	14
62a	10-16	0.15	2.96	0.015	26	1123	23
62b	10-16	0.14	3.00	0.016	22	1118	17
62c	10-16	0.08	2.80	0.016	29	1139	16
62a	11-6	0.10	2.10	0.022	33	975	20
62b	11-6	0.08	2.45	0.025	35	973	10
62c	11-6	0.08	3.03	0.025	23	975	34
63a	d	-	-	-	-	-	-
63b	-	-	-	-	-	-	-
63c	-	-	-	-	-	-	-
63a	-	-	-	-	-	-	-
63b	-	-	-	-	-	-	-
63c	-	-	-	-	-	-	-
71a	10-16	0.13	2.92	0.014	20	1120	14
71b	10-16	b	-	-	-	-	-
71c	10-16	0.14	2.48	0.017	19	1111	14
71a	11-6	0.08	2.55	0.025	31	973	49
71b	11-6	-	-	-	-	-	-
71c	11-6	0.09	2.45	0.026	29	970	50
72a	10-16	0.15	2.48	0.017	38	1120	17
72b	10-16	0.14	2.13	0.015	43	1123	10
72c	10-16	0.14	2.13	0.015	35	1113	13

(continued)

TABLE 16 (Continued)

Sampling Stations[a]	Date, 1972	Parameters Ammonia mg/1-N	Nitrate mg/1-N	Sol., Ortho-phosphate mg/1-P	Organic Carbon, Total mg/1	Specific Conductance µmhos/cm	Solids, Suspended mg/1
72a	11-6	0.09	2.45	0.026	33	973	30
72b	11-6	0.09	2.31	0.027	28	971	30
72c	11-6	0.09	2.75	0.026	46	970	27
73a	10-16	0.14	2.48	0.014	36	1143	15
73b	10-16	0.08	2.37	0.015	23	1132	20
73c	10-16	0.13	2.76	0.015	18	1119	16
73a	11-6	0.10	2.07	0.025	24	977	31
73b	11-6	0.12	2.24	0.025	33	971	26
73c	11-6	0.09	1.90	0.026	33	971	34
81a	10-16	0.16	2.48	0.016	36	1120	11
81b	10-16	b	b	b	b	b	b
81c	10-16	0.14	2.54	0.016	29	1130	19
81a	11-6	0.10	2.03	0.023	28	972	49
81b	11-6	b	b	b	b	b	b
81c	11-6	0.10	1.79	0.023	21	973	30
82a	10-16	0.07	2.50	0.016	19	1128	13
82b	10-16	0.09	2.48	0.016	43	1122	13
82c	10-16	0.15	3.00	0.016	54	1118	11
82a	11-3	c	c	c	c	c	c
82b	11-3	0.08	2.28	0.015	17	876	46
82c	11-3	c	c	c	c	c	c
82a	11-5	c	c	c	c	c	c
82b	11-5	0.08	3.06	0.027	21	952	25
82c	11-5	c	c	c	c	c	c
82a	11-6	0.09	2.20	0.025	22	969	31
82b	11-6	0.08	1.85	0.025	22	973	30
82c	11-6	0.08	1.95	0.025	37	973	26

(continued)

TABLE 16 (Continued)

		Parameters					
Sampling Stations[a]	Date, 1972	Ammonia mg/1-N	Nitrate mg/1-N	Sol., Ortho-phosphate mg/1-P	Organic Carbon, Total mg/1	Specific Conductance µmhos/cm	Solids, Suspended mg/1
83a	10-16	0.13	2.76	0.016	28	1126	18
83b	10-16	b	b	b	b	b	b
83c	10-16	0.14	2.48	0.015	26	1120	13
83a	11-6	0.08	2.55	0.025	19	969	34
83b	11-6	b	b	b	b	b	b
83c	11-6	0.08	2.23	0.026	42	970	27

a - The first digit of the location is the transect number. The second digit is the station number in the respective transect, starting with one on the east bank and increasing going west. The depth is determined by the small letter following the digits, where "a" is 3 inches from the surface, "b" is the mid-depth, and "c" is 3 inches from the bottom.

b - Due to the shallowness of the river, a mid-depth sampling could not be made.

c - Mid sampling regulations allowed for only one water sample to be taken at transects 1, 2, 4, and 8. Therefore, the water samples were taken in mid-stream, Station 2 of the respective transect at mid-depth "b."

d - Sampling Station 63 was eliminated due to the 6-foot width of the river making a third station in transect 6 impractical according to the contract.

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TABLE 17. AVERAGE OF WATER QUALITY PARAMETERS
FOR INDUSTRIAL BIO-TEST DEMONSTRATION

Parameter Averaged	Initial Value (10-16-72)	Final Value (11-6-72)
Depth (inches)	18.6	24.2
Water temperature (^{o}C)	10.4	8.8
Dissolved oxygen (mg/l)	8.31	7.83
Oxygen saturation (%)	74	67
pH	7.79	7.76
Turbidity (J.T.U.)	18.3	18.9
Ammonia (mg/l-N)	0.11	0.086
Nitrate (mg/l-N)	2.79	2.59
Soluble orthophosphate (mg/l-P)	0.017	0.024
Total organic carbon (mg/l)	27.9	30.7
Specific conductance (μmhos/cm)	1121	971
Suspended solids (mg/l)	28.3	29.8

Characterization of Bottom Muds

Initial and final creosote values for core samples taken at each sampling station are shown in Table 18. Results of selected mid-core samplings are shown in Table 19. Unfortunately, the data is difficult to interpret because of the long interval of time between cleanup and sampling at some of the stations and the unknown magnitude of redeposition of creosote-laden silt from flood water runoff of the heavy creosote deposits on the banks.

Transect 7 was cleaned 24 hours before core sampling and exhibited creosote levels of 1.3%, 0.4%, and 0.2% before, and 0.02%, 0.1%, and 0.02% after cleanup. It is not reasonable to calculate a "mass balance" of creosote before and after cleanup comprising all six transects because of the unknown amounts of redeposited creosote. Analyzing each transect individually, four of the six transects showed less creosote after cleanup than before (2, 4, 6, 7) with the composite percent removal varying from 23% at Station 2 up to 78% at Station 7. Two of the stations showed greater amounts of creosote after cleanup.

It should be pointed out that the soft sod, clay and mud banks of the Little Menomonee show very substantial quantities of creosote which were not programmed to be cleaned in this part of the study. The maneuvering of sampling crews caused creosote-containing material to be stirred up and to flow into the river in some areas no matter how carefully the work was carried out.

TABLE 18. BOTTOM SEDIMENT DATA, INITIAL AND FINAL CORE SAMPLING, LITTLE MENOMONEE RIVER

Sampling Station	Creosote, Initial %[a] (10-16-72)	Creosote, Final %[a] (11-6-72)	Change in Creosote Composition (Final - Initial), (+ or - %)
11	1.0	0.2	-0.8
12	0.3	0.4	+0.1
13	0.3	0.1	-0.2
21	0.6	0.4	-0.2
22	0.1	0.3	+0.2
23	0.6	0.3	-0.3
31	0.1	0.2	+0.1
32	0.1	0.2	+0.1
33	0.3	0.5	+0.2
41	1.8	0.1	-1.7
42	0.2	0.5	+0.3
43	0.2	0.3	+0.1
51	0.2	0.1	-0.1
52	0.3	0.2	-0.1
53	0.02	1.0	+0.98
61	0.2	0.3	+0.1
62	1.0	0.2	-0.8
71	1.3	0.02	-1.28
72	0.4	0.1	-0.3
73	0.2	0.02	-0.18
81	0.5	0.2	-0.3
82	2.3	3.0	+0.7
83	0.1	0.8	+0.7

a - The calculation for the % creosote was determined on a dry weight basis where the wet sediment sample was dried using magnesium sulfate monohydrate as the drying agent. According to Standard Methods for the Examination of Water and Wastewater, 13th edition, 1971, page 412, magnesium sulfate monohydrate is capable of combining with 75% of its own weight in water, forming a heptahydrate. Therefore the following calculations were made in determining the % creosote:

weight Mg SO_4 x 0.75 = weight of water in wet sample.
weight of wet sample - weight of water = weight of dry sample.

$$\frac{\text{grams creosote found by analysis}}{\text{weight of dry sample}} \times 100 = \text{\% creosote on a dry weight basis.}$$

TABLE 19. BOTTOM SEDIMENT DATA, MID-CORE SAMPLINGS[a] LITTLE MENOMONEE RIVER

Sampling Station	Date, 1972	Creosote mid, %
12	11-3	1.1
22	11-3	0.1
42	11-3	0.1
82	11-3	2.2
12	11-5	0.05
22	11-5	0.3
42	11-5	0.1
82	11-5	0.8

a - Mid sampling regulations allowed for one bottom sample to be taken at transects 1, 2, 4, and 8 on 11-3-72 and 11-5-72. Therefore, the bottom sediments were taken in mid-stream, Station 2 of the respective transect.

Redeposition of creosote due to flooding and receding waters certainly could explain finding creosote levels at previously cleaned sites as well as the variable pattern obtained. The results obtained at Station 7, however, indicate the thoroughness with which the removal system can effectively operate when environmental variables are minimum.

SECTION 8

COMPARISON OF TWO METHODS AND RECOMMENDATIONS FOR PHASE II

COMPARISON OF METHODS

As stated in the Introduction of this report, the performance of Phase II was to be awarded to the contractor's system that best met the design goals of the RFP. A comparison of the two systems for each of the design goals follows.

Compact Size and Mobility

The two systems differ radically in size. The Rex Chainbelt system made use of two trailer-mounted water treatment devices and a rather large "river sweeper" which was fairly difficult to launch in the river. However, within 10 hours of arrival of the equipment on-scene, setup was complete and contaminated sediment was being removed. On the other hand, the Industrial Bio-Test/R P Industry system consisted of much smaller equipment, as evidenced by the fact that the entire system was transported from Massachusetts in a 40-foot rented moving van. However, the system, which was automated to the maximum extent possible and therefore was more complex than the other, was not ready to commence removal operation until the third day after its arrival on-scene.

When a comparison must be made on the basis of total time elapsed from time of notification of a spill at a given location to the time when actual removal operations begin, there is probably little difference between the two systems. The Rex Chainbelt system using large equipment will take longer to reach the destination, but less time to put into operation. The Industrial Bio-Test/R P system will be more rapidly transported (it could probably be packaged for air delivery in an L-130 aircraft), but its setup at the spill site will require more time.

Minimal Damage to Stream Bed and Banks

Both systems performed well in this regard. However, if strict supervision of this aspect is not imposed, there is a potential for a problem with both. Any cleanup activity in a stream or on its banks will disturb them to some degree, but by judiciously choosing the location for deploying its heavy equipment, the Rex Chainbelt system was able to enter and leave the stream with very little damage. The only problem with the streams, banks or beds which arose during the Industrial Bio-Test/R P Industries demonstration was the displacement of a small amount of creosote and mud from the banks into the stream when workers were working on the banks. This situation, however, was caused by the fact that the river was at or near flood stage during almost the entire period when cleanup operations were in progress. This flooding turned the banks into a jelly-like consistency.

Minimum Resuspension of Bottom Muds

As evidenced by the fact that the concentration of suspended solids and creosote in the river did not vary significantly before, during, and after the cleanup operations, the two systems met this requirement. However, a sheen of oil/creosote was observed on the surface of the river during both operations whenever the bottom mud or banks were disturbed. The sheen during the Rex Chainbelt demonstration appeared to be more prevalent when the "river sweeper" was repositioned by personnel wading into the river. This activity in the river could easily be minimized by motorizing the spuds and by using tow ropes. The previously mentioned redisposition of mud from the banks during the Industrial Bio-Test/R P Industries demonstration also caused a significant sheen on the river, but as stated above, this situation was a "freak of nature" and would have been nearly impossible to avoid, given the flooding that was experienced. Both contractors did use sorbent oil booms to prevent the sheen from being carried downstream of their demonstration segments by the current.

Solids-Water Separation

As mentioned in the Introduction, for a bottom cleanup to be economically feasible, the volume of materials to be transported from the site and disposed of have to be minimized. Both systems performed well in regard to reducing the volume of bottom mud that had to be disposed of. Typical suspended solids concentrations of the Rex Chainbelt and Industrial Bio-Test sludges were 201,000 mg/l and 250,000 mg/l, respectively. The water removed from the original creosote/mud slurry pumped from the river was treated by both systems to a water quality better than that of the river water itself. For instance, the Rex Chainbelt and Industrial Bio-Test processes produced typical effluent creosote concentrations of 2.3 mg/l and less than 0.1 mg/l respectively, as compared with a typical concentration of 11 mg/l in the river water. Similarly, suspended solids levels in the systems' effluents were significantly lower than in the river water.

The systems both effectively reduced the volume for disposal while not sacrificing the stream's water quality.

Acceptable Discharge of Effluent

Both systems discharged their effluents in a manner that minimized the damage to the stream banks and bed from erosion. Neither the 100-gpm flow from the Rex Chainbelt system nor the 10-gpm flow from the Industrial Bio-Test system was sufficient to create a turbulence problem when discharged directly into the flow of the river.

Acceptable Disposal of Sludges

The sludges generated during the course of both cleanup demonstrations were disposed of at a state-approved landfill site nearby.

Effectiveness of Creosote Removal

As stated in earlier sections of this report, even though every precaution was taken to place the two demonstrations on the same basis, several uncontrollable factors affected the comparability of the two methods. Despite the choice of October, normally the dryest month of the year, for the demonstration, the last 2 weeks of the month were very wet and the river flow was adversely affected to the point where Industrial Bio-Test operations had to be halted for a week. In addition, the high flow probably recontaminated the areas that had been cleaned previous to the flood.

During the course of both operations, it was discovered that the river bottom varied from several feet of silt in some places to gravel in others and hard clay in others. This variability in consistency also resulted in a variability in creosote contamination with the high creosote concentrations being detected in silted areas and much lower concentrations in the gravel and clay areas where the natural current scoured the bottom.

When the discrepancies mentioned above are taken into account, a comparison of both methods' removal efficiencies does not yield a clear advantage to either Rex Chainbelt or Industrial Bio-Test. For instance, calculations from the data in Table 20 reveal that average creosote concentrations in the Rex Chainbelt segment were reduced by 58% during the cleanup, while only being reduced by 39% in the Industrial Bio-Test segment. However, since sampling was only done after the Bio-Test demonstration was completed, the 300 feet cleaned up before the flood could have been recontaminated. Indeed, it can be seen from Table 20 that creosote concentrations increased at two of the four

TABLE 20. AVERAGE CREOSOTE CONCENTRATIONS (% BY WEIGHT) IN THE DEMONSTRATION SEGMENTS*

Contractor - Time	500 ft	400 ft	300 ft	200 ft	100 ft	0	Avg Total Segment
Rex Chainbelt - Before	1.8	10.8	.64	.33	.36	.36	2.38
Rex Chainbelt - After	1.3	2.0	1.55	.34	.46	.14	.97
Industrial Bio-Test - Before	.43	.17	.73	.17	.6	.63	.46
Industrial Bio-Test - After	.33	.30	.30	.43	.25	.05	.28

* As determined by hexane extractables method on page 37.

locations in this portion of the demonstration segment. If data from these four locations is discarded, then the average reduction of creosote at the remaining two locations is 75%.

These data cannot be used, therefore, as the basis for awarding the Phase II cleanup, but they do demonstrate that each system was capable of solving the problem of removing spilled hazardous materials from the bottoms of small watercourses.

RECOMMENDATIONS FOR PHASE II

Determination of Safe Creosote Residual

During the conduct of Phase I it became apparent that it would be virtually impossible to remove all traces of creosote from the river bed. However, there is no toxicologic data available on which to establish a permissible level of creosote that could be left in the sediment. It was decided that the contractor who was awarded Phase II should conduct tests appropriate to determining the maximum level of creosote in the sediment which would not present a public health hazard or prevent the ecological restoration of the stream. The ecological tests should be conducted in such a manner that the conditions of the stream will be closely simulated and should employ authentic creosote-contaminated sediment from the Little Menomonee River instead of fresh creosote. The tests to determine the public health data should be conducted using Little Menomonee River mud to establish a level at which irritation will not occur when the sediment is contacted by the skin.

Development of Field Test for Creosote Residual

During the conduct of Phase I, difficulty was experienced in determining when a section of river bottom had been cleaned sufficiently to allow proceeding to another section. To alleviate this problem it was decided that the Phase II contractors should develop a "spot test" to determine if the creosote concentration was below the permissible level. The test should not require the use of sophisticated laboratory equipment and should be able to be conducted quickly at the operations site to minimize equipment down time during the determination.

Removal of Creosote Contamination from River Banks

Difficulty was encountered during the Industrial Bio-Test Phase I operation with the disposition of creosote/mud from the banks into the river. Further investigation revealed that certain areas of the banks were soaked with creosote. It was decided that the Phase II contractor should, when necessary, cut back those banks that are contaminated with creosote prior to bottom cleanup operations. The concentration remaining in the banks should be below the permissible level so that the bank will not present a public health hazard.

Prevention of Recontamination from Upstream

The high flow conditions experienced during the Industrial Bio-Test operations and the redisposition of creosote attributed to the flow reinforced the decision to initiate Phase II operations at the source of the creosote contamination and work downstram. State of Wisconsin Department of Natural Resources assurances should also be sought that no other creosote is entering the stream at the source.

Selection of a Contractor

Since both systems had demonstrated that they could meet the design goals of the RFP and neither showed a clear overall superiority, it was decided to award the Phase II work on the basis of cost. A revised scope of work was prepared based on the above recommendations and the two contractors were requested to submit detailed technical and business proposals for evaluation. Both contractors submitted acceptable proposals and the Phase II contract was awarded to Rex Chainbelt on the basis of lower cost.